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ECOLOGY AND PALEOECOLOGY OF SOME CALIFORNIA FORAMINIFERA. PART I. THE FREQUENCY DISTRIBUTION OF RECENT FORAMINIFERA OFF CALIFORNIA[1]

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ABSTRACT—Frequency studies of Recent benthonic Foraminifera off California show two faunal gradations, a bathymetric change and a north-south variation. Oxygen, salinity, and temperature measurements are correlated with faunal variations. Temperature may be the main over-all controlling factor; however, two incongruities exist. First, the shallow-water species off San Diego occur in deeper and colder water off San Francisco. Secondly, in the deeper waters off the northern and southern parts of the California coast, the temperature is about the same for equivalent depths, yet there is a marked difference in the Foraminifera.

The species of *Uvigerina* are good zone determinants in the northern areas. Slender, delicately costate species occur in the lower neritic zone, the more heavily costate species are predominant in the bathyal zone, hispid and spinose species are most abundant in the upper abyssal zone and a finely papillate species is diagnostic of the lower abyssal zone.

INTRODUCTION

As an approach toward a better understanding of foraminiferal patterns of distribution and ecologic implications thereof, a general frequency study was made of the benthonic Foraminifera in bottom samples and cores located along three general lines of profile across the continental shelf and down the slope (fig. 1). The southernmost profile, located off San Diego, extends about 17 miles to sea from a water depth of about 40 feet across the gently sloping shelf, across Loma Sea Valley, Coronado Bank and down into the San Diego Trough. The second profile extends about 75 miles to sea from Point Arguello, beginning in about 60 feet of water and continuing out to a depth of almost 12,000 feet on the deep sea floor. The third and northernmost profile is made up of scattered samples extending from the beach in San Francisco Bay, westward across Cordell Bank to a depth of about 6900 feet. This profile is about 80 miles in length.

A total of 63 samples were used in plotting up the three profiles of this investigation; however, many additional samples were examined, especially in the San Francisco region. A few of the samples from the San Francisco area were loaned by the California Academy of Science and these had already been washed and concentrated. The Point Arguello samples were also washed

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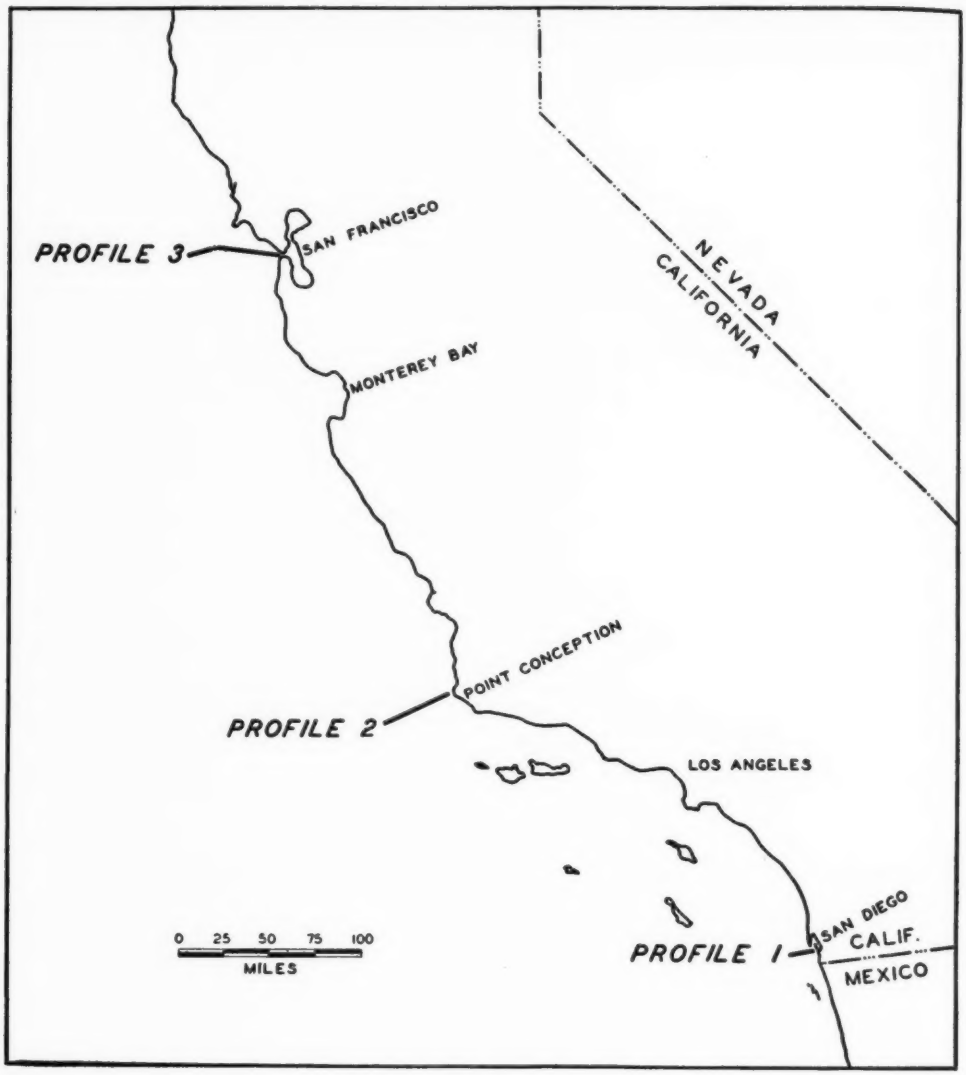

FIG. 1—Location map.

and partially concentrated before being made available to the writer. In nearly all other cases, an original sample of 40 grams (dry weight) was used. The frequency counts were based upon a minimum of 300 specimens excepting in a very few cases in which there was a paucity of Foraminifera. The pelagic species were counted separately, lumped together, and the pelagic-benthonic ratio is given with the frequency charts.

To depict graphically the correlation of ecologic changes with variations in foraminiferal frequencies, the depth, temperature, oxygen content, and salinity data are plotted along with the cumulative frequency graphs.

The writer is indebted to the following people for their kindness and coöperation in aiding this study: Dr. K. O. Emery, Geology Department, University of Southern California, for many suggestions and for furnishing samples from the collections of the University of California Division of War Research; Richard Terry of the Hancock

Foundation, University of Southern California, for drafting the charts; R. F. Dill, Navy Electronics Laboratory, San Diego, California, and to the Scripps Institution of Oceanography for supplying samples off Point Arguello; and Dr. G. D. Hanna and Mr. C. C. Church, California Academy of Sciences and the Tide Water Associated Oil Company respectively, for loaning some of the bottom samples used in the San Francisco profile.

PREVIOUS WORK

Several taxonomic papers describing Recent Foraminifera in the coastal waters of California are listed in the bibliography. Articles relating to the ecology and patterns of distribution of the Foraminifera in this area are relatively few in number. The first work of this kind was that of Moyer (1929) in which a rough zonation was made from sea level to a depth of 2400 feet. Natland (1933) published the first detailed study of the depth-temperature relationships of Recent Foraminifera off California. He established five faunal zones from sea level to a depth of about 6000 feet. Schenck (1940) reported the occurrence of *Rotalia beccarii* in San Francisco Bay and *Elphidium crispum* in the littoral zone of the open ocean coast. Butcher (1951) presented depth ranges of Recent Foraminifera off San Diego in the Coronado Bank area and Phleger (1951) has presented additional data on depth ranges and displaced foraminiferal faunas. The Foraminifera of the deep basins have been studied by Crouch (1952) and he has found evidence that temperature is the controlling factor there. The approach in some of these studies has been qualitative and others quantitative; all have indicated interesting correlations of foraminiferal assemblages with depth and temperature changes.

FAUNAL ZONATION

The three lines of samples were selected from the southern, central, and northern regions off California in order to reveal general changes in the patterns of distribution from the warmer to the colder water areas. The northern and southern lines of samples cross Cordell and Coronado Banks respectively, reflecting faunal changes there. The frequency charts (figs. 2–4 incl.) and table I depict dominant species in given depth ranges and exhibit the nature of the overlapping ranges. On the steeper slopes and perhaps elsewhere there has been some downward displacement of faunas as may be observed at the outer end of the San Diego frequency chart, figure 2. *Cibicides fletcheri* and *Rotalia versiformis* were found to exceed 5% in two samples at the deep end of the profile and it may be observed that their highest typical and continuous frequency occurrence is in the shallow water area near shore. Other suggestions of downward displacement may be observed in the other two frequency charts. In view of this condition only the upper limits of high frequency are generally dependable.

In figures 2–4 inclusive, nearby stations or those reflecting the same faunal patterns at equivalent depths are averaged together. The data for the temperature, oxygen, and salinity curves were obtained from Revelle (1949) and from Sverdrup (1942, 1943). Inasmuch as the measurements at these stations do not extend to the bottom, it was necessary to select stations in deeper water and to assume that the readings there would be approximately the same as the conditions along the bottom profiles at equivalent depths. Readings for two or more periods of the year were used in order to arrive at the approximate annual variation. The variation is shown in all cases excepting for the salinity curve in the San Diego profile. In this case the range in salinity for any one station appeared to be less than one part per thousand.

The depth zones referred to are those presented by Ladd (1950–51). The faunal assemblages of these zones are presented below. In speaking of the restriction of species to the various zones, it should be emphasized that restriction of abundant or high frequency occurrences is meant. Rare or very low frequency occurrences may demonstrate exceedingly wide ranges for some of the species.

Brackish water (polyhaline) zone.—In San Francisco Bay the salinity ranges from about 20°/$_{oo}$ to 30°/$_{oo}$ (Anon., 1945). In table I, *Rotalia beccarii* is the dominant species in the bay. Along the general coastline, one might expect this species to pre-

dominate in shallow waters that are consistently brackish. The affinity of *R. beccarii* and its variants for brackish water has been noted by many authors (Natland, 1933; Hedberg, 1934; Post, 1951; Bandy, in press). Along the rest of the California coast there are few typically brackish water areas and the fauna of the following zone is dominant.

Middle neritic zone.—This zone embraces the depth range from low tide to about 150 feet (50 meters). The assemblage in this zone is usually dominated by *Buliminella elegantissima*, *Nonionella basispinata*, and *Nonionella miocenica* var. *stella*. In addition to these cosmopolitan species, the following species seem to be restricted to the southern profile: *Elphidium translucens*, *Rotalia lomaensis*, and *Trochammina pacifica*. Conversely, *Elphidiella hannai* and *Gaudryina arenaria* appear to prefer the colder northern waters.

The typical assemblage occurs off San Diego usually in water less than 100 feet deep with a water temperature range of about 13–17.5°C., whereas off Point Arguello and San Francisco, the fauna is found down to depths of nearly 400 feet with a temperature range of about 8.5–13.2°C. At the outset of this investigation, the reverse was anticipated. It seemed logical to expect species adapted to shallow colder water in the northern profiles to be found in deeper cooler waters farther south, rather than in warm, shallow near-shore areas. The reason for this discrepancy is not known.

Lower neritic zone.—This zone embraces the 150 to 600 foot depth range (50–200 meters). In areas of high productivity, especially in the southern profile, *Cassidulina californica*, *Cassidulina limbata*, *Cassidulina quadrata*, and *Cassidulina tortuosa* are of extremely high frequency, making up the preponderance of the fauna at nearly all stations. *Angulogerina angulosa* is usually an important member of the fauna also. Farther north the *Cassidulina* assemblage is absent or more or less restricted to banks, such as Cordell Bank off San Francisco. Here, *Cassidulina limbata* and a variation of *Cassidulina californica* comprised the entire *Cassidulina* assemblage. In the northern areas there are relatively fewer Foraminifera and the faunas consist mostly of *Uvigerina hollicki*, *Uvigerina tenuistriata*, and *Angulogerina angulosa*. There is a transitional biofacies between the middle and lower neritic assemblages off San Diego. It is character-

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EXPLANATION OF PLATE 21

FIGS. *1*—*Quinqueloculina angulo-striata* Cushman and Valentine, ×33. *a*, side view; *b*, apertural view; *c*, opposite side; hypotype, USC No. 3408. (p. 177)

2—*Triloculina inornata* d'Orbigny var. *longidentata* Bandy, n. var., ×23. *a*, side view; *b*, apertural view; *c*, opposite side; holotype, USC No. 1042. (p. 178)

3—*Quinqueloculina lamarckiana* d'Orbigny, ×33. *a*, side view; *b*, apertural view; *c*, opposite side; hypotype, USC No. 3407. (p. 177)

4—*Spiroloculina dentata* Cushman and Todd, ×50. *a*, side view; *b*, apertural view; hypotype, USC No. 3410. (p. 177)

5—*Proteonina atlantica* Cushman, ×23. *a*, side view; *b*, apertural view; hypotype, USC No. 3368. (p. 177)

6—*Pyrgo inornata* (d'Orbigny), ×33. *a*, side view; *b*, apertural view; hypotype, USC No. 3406. (p. 177)

7—*Trochammina pacifica* Cushman and McCulloch, ×70. *a*, ventral view; *b*, edge view; *c*, dorsal view; hypotype, USC No. 3413. (p. 177)

8—*Nonion barleeanus* (Williamson), ×50. *a*, side view; *b*, apertural view; hypotype, USC No. 3386. (p. 177)

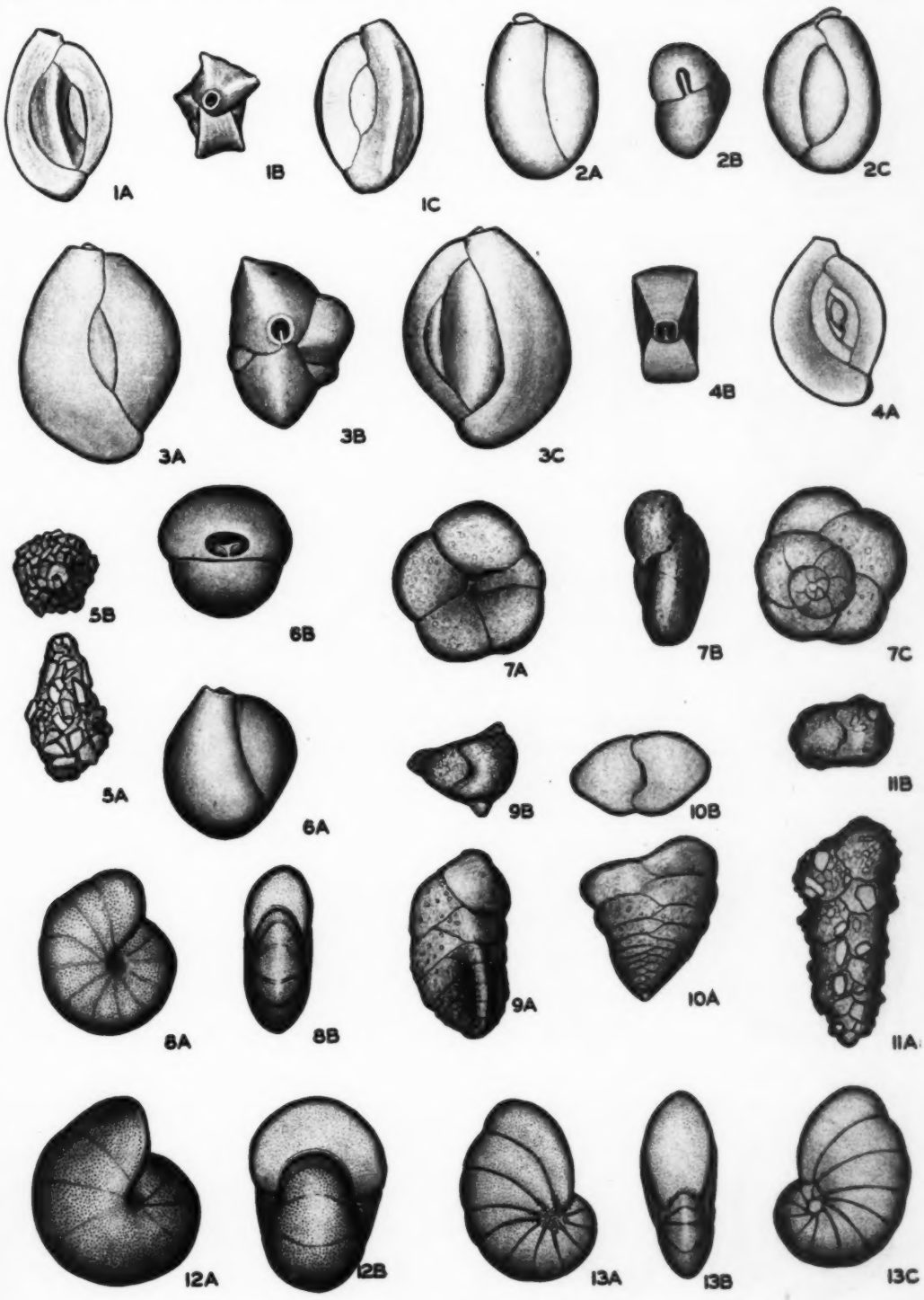
9—*Gaudryina arenaria* Galloway and Wissler, ×33. *a*, side view; *b*, apertural view; hypotype, USC No. 3365. (p. 177)

10—*Textularia conica* d'Orbigny, ×33. *a*, side view; *b*, apertural view; hypotype, USC No. 3411. (p. 177)

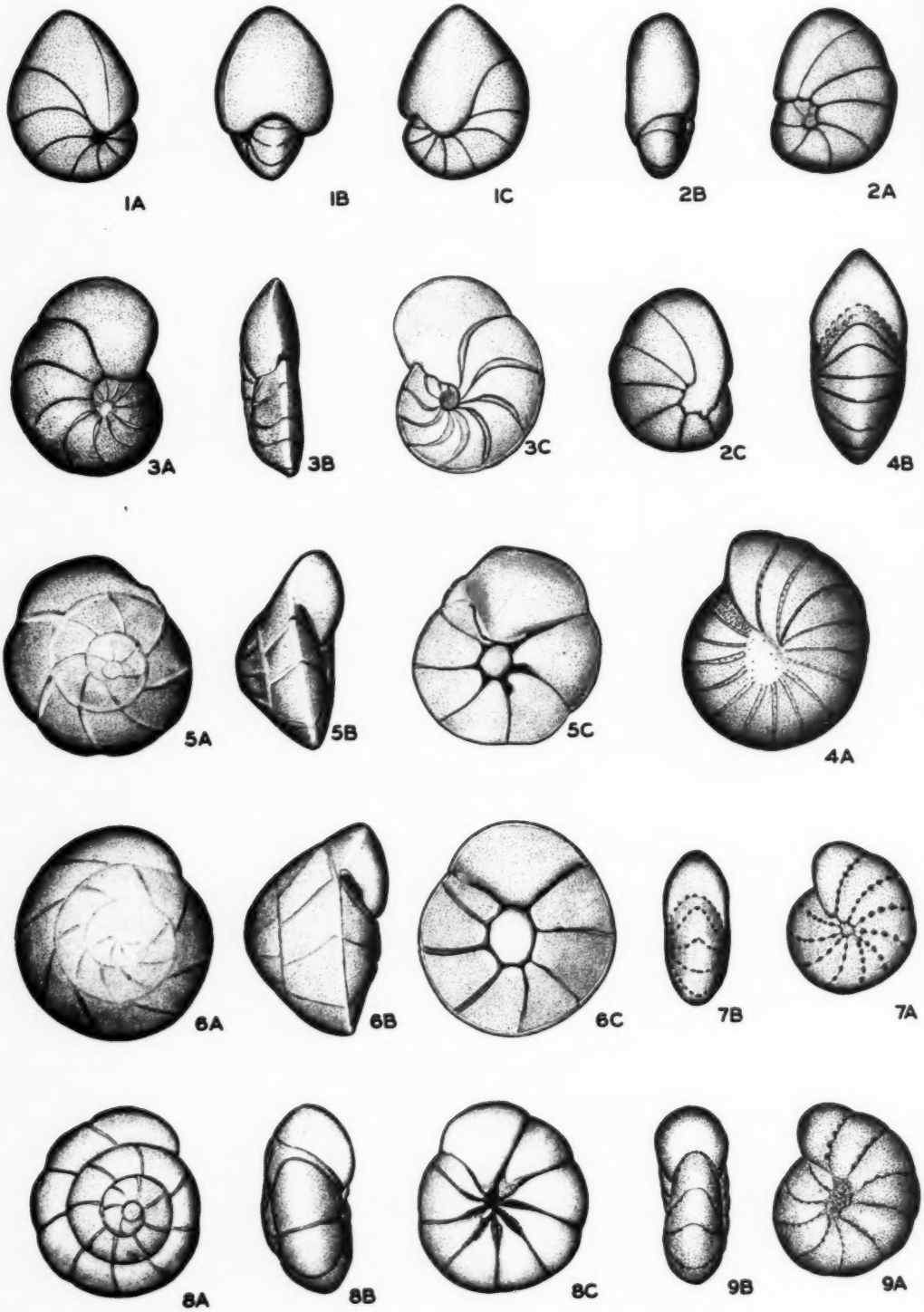
11—*Textularia foliacea* Heron-Allen and Earland, ×23. *a*, side view; *b*, apertural view; hypotype, USC No. 3412. (p. 177)

12—*Nonion pompilioides* (Fichtel and Moll), ×73. *a*, side view; *b*, apertural view; hypotype, USC No. 3387. (p. 177)

13—*Nonionella basispinata* (Cushman and Moyer), ×50. *a*, side view; *b*, apertural view; *c*, opposite side; hypotype, USC No. 3388. (p. 177)



Bandy, Frequency Distribution of Recent Foraminifera



Bandy, Frequency Distribution of Recent Foraminifera

ized by *Rotalia versiformis* and *Cibicides fletcheri* and by a mixture of the typical representatives of the middle and lower neritic zones. This assemblage is listed in table I for the depths of 100–200 feet.

The species of the lower neritic zone are accommodated to a temperature range of about 8–13°C., about the same range that characterizes the middle neritic zone in the northern profiles. The oxygen range is about 1.4 to 5.4 ml/l and the salinity is above 33.2°/₀₀. The oxygen minimum is much lower than that of the preceding zone but the maximum is well within the range of that of the middle neritic zone. Temperature is hardly a critical environmental factor inasmuch as the range is almost the same as the zone off Point Arguello and San Francisco. As compared with the preceding zone, the important factors for this biofacies must include reduced turbulence, reduced turbidity, and a rather high oxygen content with a seasonal minimum. The differences between the northern and southern faunas of this zone do not seem to result from temperature differences.

Bathyal zone.—This zone ranges from 600 to 6000 feet (200–2000 meters). Only the upper half of the bathyal zone is represented off San Diego, because the San Diego Trough is about 3350 feet deep. The entire zone is represented in the other two profiles. Off San Diego, the bathyal zone is dominated by *Planulina ornata* which usually exceeds 20 or 25 percent of the benthonic population. Associated species consist of miliolids, *Textularia conica* and *Textularia foliacea*. *Planulina ornata* appears to increase in abundance with depth off the seaward side of Coronado Bank.

In the northern areas off Point Arguello and San Francisco, the bathyal zone is characterized by an abundance of *Uvigerina peregrina*. In these profiles the *U. peregrina* assemblage may be further subdivided into about three subzones. The upper bathyal subzone, ranging from 600 to 1500 feet, is characterized by high frequencies of both *Bolivina spissa* and *Angulogerina angulosa*. The next subdivision, the middle bathyal subzone ranges from about 1500 to 3000 feet and exhibits important abundances of *Cassidulina delicata*, *Cassidulina cushmani*, *Epistominella pacifica*, *Epistominella smithi*, and *Epistominella evax*. The occurrence of *Epistominella pacifica* at greater depth in the San Francisco profile is an anomaly perhaps explained by its displacement down the slope of the continental shelf. Unfortunately, insufficient samples were available in the bathyal zone of the San Francisco profile to determine the upper limits of *Epistominella pacifica* here. The lower bathyal subzone, ranging from 3000 to 6000 feet, is characterized by the appearance of *Bulimina striata* var. *mexicana*, *Bulimina subacuminata*, *Cassidulina translucens*, and *Cassidulina lomitensis*. These species of *Cassidulina* were not of importance in the *Cassidulina* assemblage of the lower neritic zone and, as indicated in Natland's work (1933), they seem to be characteristic of the

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EXPLANATION OF PLATE 22

FIGS. *1*—*Nonionella labradorica* (Dawson), ×73. *a*, side view; *b*, apertural view; *c*, opposite side; hypotype, USC No. 3367. (p. 177)

2—*Nonionella miocenica* Cushman var. *stella* Cushman and Moyer, ×50. *a*, side view; *b*, edge view; *c*, opposite side; hypotype, USC No. 3389. (p. 177)

3—*Cibicidina basiloba* (Cushman) var. *nitidula* Bandy, n. var., ×33. *a*, ventral side; *b*, apertural view; *c*, dorsal view; holotype. USC No. 1043. (p. 178)

4—*Elphidiella hannai* (Cushman and Grant), ×33. *a*, side view; *b*, apertural view; hypotype, USC No. 3363. (p. 176)

5—*Rotalia versiformis* Bandy, n. sp., ×100. *a*, dorsal view; *b*, apertural view; *c*, ventral view; holotype, USC No. 3047. (p. 179)

6—*Rotalia lomaensis* Bandy, n. sp., ×100. *a*, dorsal view; *b*, edge view; *c*, ventral view; holotype, USC No. 3046. (p. 179)

7—*Elphidium articulatum* (d'Orbigny), ×50. *a*, side view; *b*, apertural view; hypotype, USC No. 3362. (p. 176)

8—*Rotalia beccarii* (Linnaeus), ×50. *a*, dorsal view; *b*, edge view; *c*, ventral view; hypotype, USC No. 3369. (p. 177)

9—*Elphidium translucens* Natland, ×50. *a*, side view; *b*, apertural view; hypotype, USC No. 3403 (p. 176)

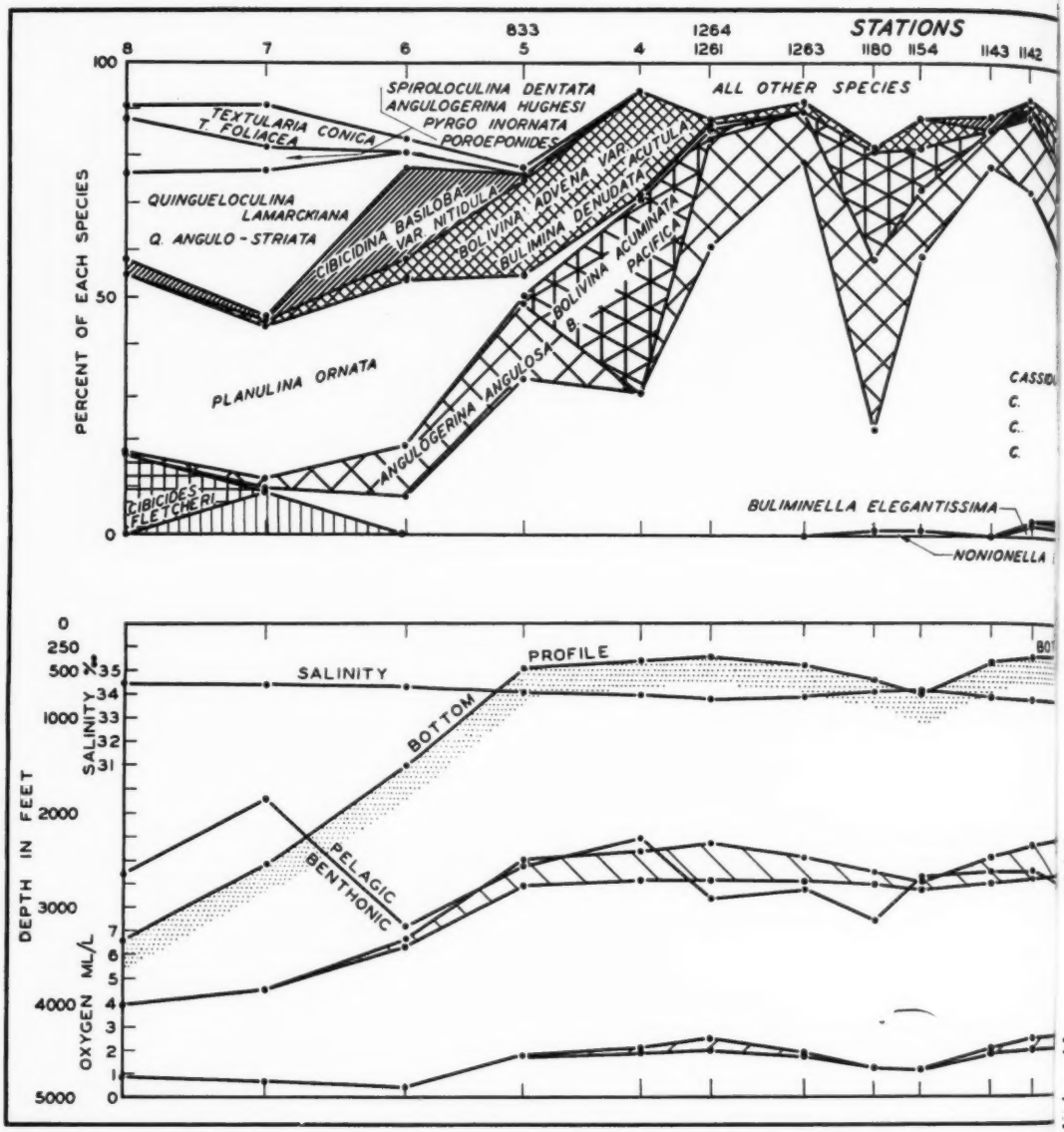
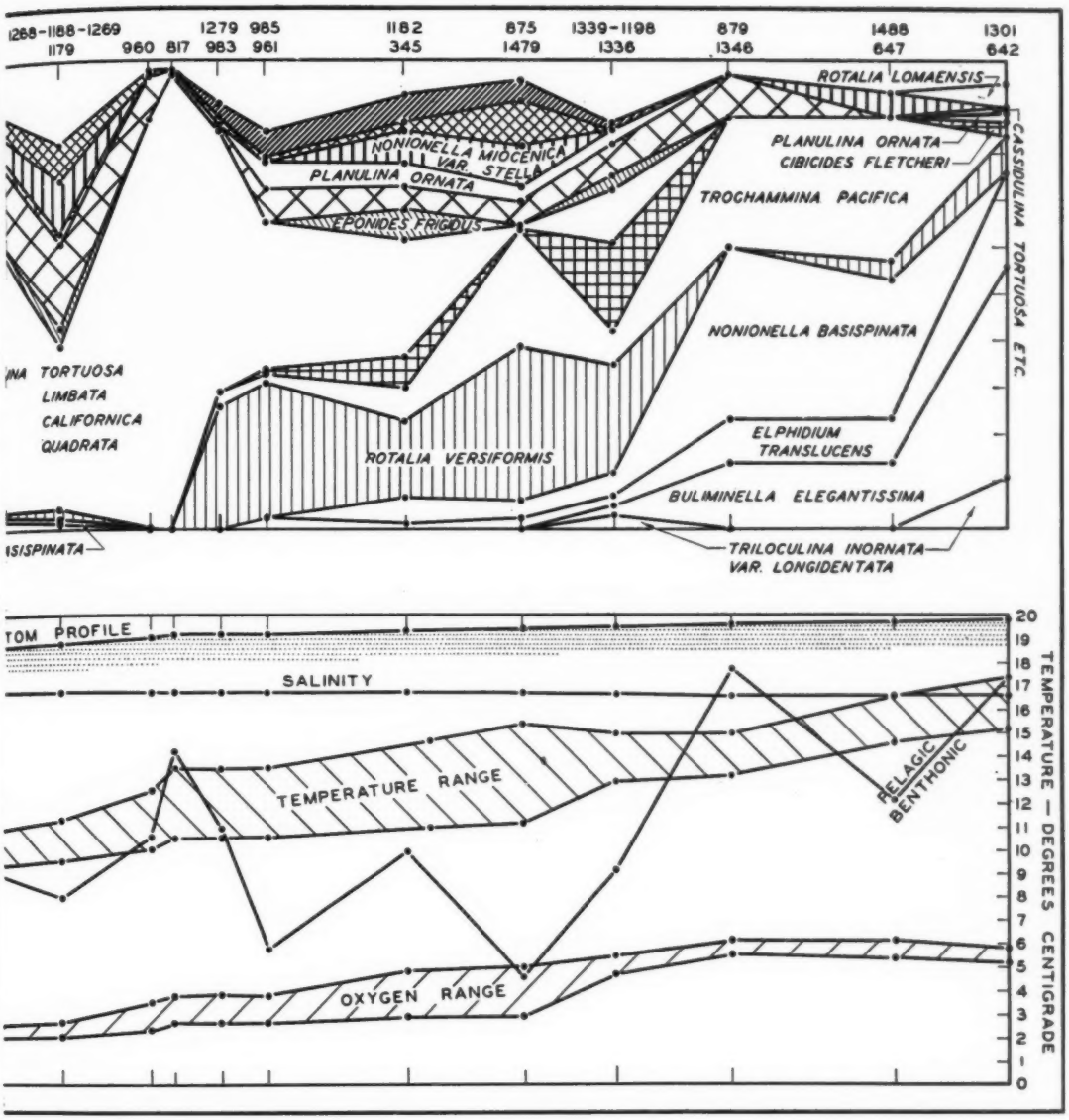


FIG. 2—Profile 1, frequency distribu

bathyal zone between the depths of about 2000 and 4000 feet. It is interesting to note that Parker (1948) found *Uvigerina peregrina* to be the dominant species of the upper bathyal zone along the Atlantic coast. Phleger and Parker (1951, pt. II, p. 18) also report this species in the bathyal zone of the Gulf of Mexico. In both of the above-mentioned reports, the temperatures involved are about 4 to 6 or 8°C. which agrees generally with part of the bathyal temperature range found in the present investigation.

The temperature in the bathyal zone ranges from about 8.8° at a depth of 600 feet to about 1.8°C. at the 6000 foot depth. The oxygen content ranges from 3.6 ml/l near the upper limit of the zone to a minimum of about 0.4 ml/l at 2000 feet, below which it increases slightly to about 3.0 ml/l near the



tion of the Foraminifera off San Diego.

outer ends of the profiles in the abyssal zone. In the bathyal zone the salinity fluctuates only slightly on either side of 34°/₀₀. In assessing these changes, it would seem that the salinity factor can be ruled out as of little importance; however the oxygen minimum at about 2000 feet might restrict the distribution of some species. For example *Uvigerina peregrina* crosses the oxygen minimum with little change whereas the accessory species reflect considerable frequency change within this region. The progressive decrease in temperature with depth is undoubtedly a critical or limiting factor for many species.

Curiously enough, the faunal difference between the San Diego and the northern profiles is great; however, at any given depth in the bathyal zone, the temperature and oxygen readings are not very different. The

TABLE I. COMPARISON OF FAUNAL ZONES*

	Profile No. 1 San Diego	Profile No. 2 Point Arguello	Profile No. 3 San Francisco
Brackish Shallow Water Zone			San Francisco Bay Beach 7.2–18.0°C. Salinity 20.509–29.810‰ Rotalia beccarii (Linnaeus)
Middle Neritic Zone 0–150 ft.	40–100 feet 13–17.5°C. Salinity 33.3‰ Oxygen 5.2–6.4 ml/l. Nonionella basispinata (Cushman & Moyer) Trochammina pacifica Cushman Nonionella miocenica var. stella Cushman & Moyer Rotalia lomaensis Bandy Elphidium translucens Natland 100–200 feet 10.6–15.4°C. Salinity 33.3–33.9‰ Oxygen 3.1–6.4 ml/l. Rotalia versiformis Bandy Cassidulina californica Cushman & Hughes Cassidulina limbata Cushman & Hughes Note: Cassidulina—Less than 30% Cassidulina quadrata Cushman & Hughes Cassidulina tortuosa Cushman & Hughes Nonionella miocenica var. stella Cushman & Moyer Eponides frigidus (Cushman) Trochammina pacifica Cushman Cibicides fletcheri Galloway & Wissler	240 feet 8.6–13.2°C. Salinity 33.8–34.2‰ Oxygen 3.2–6.2 ml/l. Nonionella miocenica var. stella Cushman & Moyer Buliminella elegantissima (d'Orbigny) Eponides frigidus (Cushman) Nonionella basispinata (Cushman & Moyer) Bulimina denudata Cushman & Parker	120–360 feet 8.5–13.2°C. Salinity 33.2–33.8‰ Oxygen 3.6–6.2 ml/l. Elphidiella hannai (Cushman & Grant) Buliminella elegantissima (d'Orbigny) Gaudryina arenaria Galloway & Wissler Nonionella miocenica var. stella Cushman & Moyer Eponides frigidus (Cushman)
Lower Neritic Zone 150–800 ft. (150–600 ft.)	200–800 feet 8.8–13.6° C. Salinity 33.6–34.2‰ Oxygen 1.8–4.7 ml/l. Cassidulina californica Cushman & Hughes Cassidulina limbata Cushman & Hughes Cassidulina quadrata Cushman & Hughes Note: Cassidulina greater than 30% Cassidulina tortuosa Cushman & Hughes Angulogerina angulosa (Williamson) Bolivina advena var. acutula Bandy Bolivina acuminata Natland Bolivina pacifica Cushman & McCulloch Bulimina denudata Cushman & Parker	612 feet 8.2–10.5°C. Salinity 33.6–43.0‰ Oxygen 1.8–3.6 ml/l. Uvigerina hollicki Thalmann Uvigerina tenuistriata Reuss Cassidulina limbata Cushman & Hughes Angulogerina angulosa (Williamson) Bulimina denudata Cushman & Parker	400–700 feet 7.4–13°C. Salinity 33.2–34‰ Oxygen 1.4–5.4 ml/l. Uvigerina hollicki Thalmann Uvigerina tenuistriata Reuss Angulogerina angulosa (Williamson) Proteonina atlantica Cushman Nonionella labradorica (Dawson) Globobulimina pacifica Cushman Bolivina pacifica Cushman & McCulloch Nonionella miocenica var. stella Cushman & Moyer Nonionella basispinata (Cushman & Moyer) 400 feet (Cordell Bank) 7.8–10.4°C. Salinity 33.6–34.0‰ Oxygen 2.3–4.9 ml/l. Cassidulina californica Cushman & Hughes Cassidulina limbata Cushman & Hughes Angulogerina baggi (Galloway & Wissler)

Bathyal Zone 800–6,000 ft. (600– 6,000 ft.)	1,000–3,350 feet 3.9–6.7°C. Salinity 34.3–34.5‰ Oyxgen 0.4–0.9 ml/l. Planulina ornata (d'Orbigny) (Greater than 25%) Quinqueloculina lamarckiana d'Orbigny Quinqueloculina angulo-striata Cushman & Valentine Spiroculina dentata Cushman & Todd Pyrgo inornata (d'Orbigny) Poroeponides cribrorepandus Asano & Uchio Textularia conica d'Orbigny Textularia foliacea Heron-Allen & Earland	1,200 feet 6.2–6.6°C. Salinity 34.1‰ Oxygen 0.8–1.8 ml/l. Uvigerina peregrina Cushman Bolivina spissa Cushman Angulogerina angulosa (Williamson) 1,800–2,400 feet 4.0–5.5°C. Salinity 34.2-34.4‰ Oxygen 0.4–0.6 ml/l. Uvigerina peregrina Cushman Bolivina spissa Cushman Cassidulina delicata Cushman Epistominella pacifica (Cushman) Epistominella smithi (R. E. & K. C. Stewart) 2,800 feet 3.8–4.4°C. Salinity 34.3‰ Uvigerina peregrina Cushman Bulimina striata var. mexicana Cushman Cassidulina translucens Cushman & Hughes Cassidulina lomitensis Galloway & Wissler	1,700 feet 5.2–5.5°C. Salinity 34.3‰ Oxygen 0.4 ml/l. Epistominella evax Bandy Uvigerina peregrina Cushman
Upper Abyssal Zone 6,000–8,000 ft.		6,000–7,800 feet 1.8–2.2°C. Salinity 34.6-34.7‰ Oxygen 1.8-2.2 ml/l. Uvigerina hispida Schwager Uvigerina proboscidea Schwager Bulimina barbata Cushman Bulimina rostrata H. B. Brady Bulimina striata var. mexicana Cushman Gyroidina gemma Bandy Gyroidina soldanii d'Orbigny	6,000–6,900 feet 1.9–2.2°C. Salinity 34.6-34.7‰ Oxygen 1.6-1.9 ml/l. Epistominella pacifica (Cushman) Uvigerina proboscidea Schwager Uvigerina hispida Schwager Bulimina striata var. mexicana Cushman Buliminella exilis (Brady) Eponides tenera (Brady) Bulimina affinis d'Orbigny Cassidulina delicata Cushman
Lower Abyssal Zone 8,000–12,000 ft.)		11,760 feet 1.53°C. Salinity 34.66–34.68‰ Oxygen 2.9–3.0 ml/l. Uvigerina senticosa Cushman Hoglundina elegans (d'Orbigny) Nonion pompilioides (Fichtel & Moll) Nonion barleeanus (Williamson) Gyroidina gemma Bandy Gyroidina soldanii d'Orbigny Bulimina rostrata Brady	

* Species arranged in order of abundance and importance.

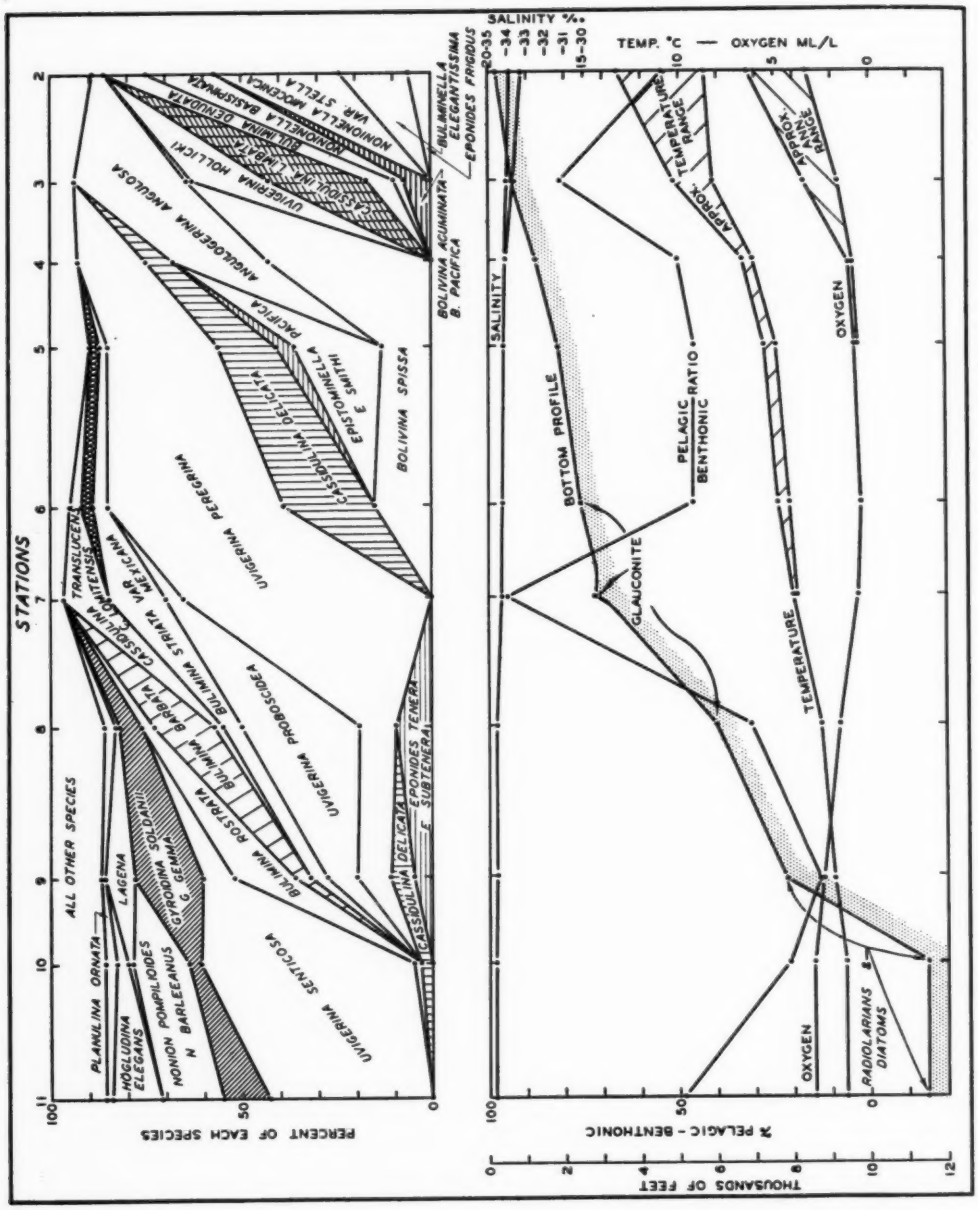


FIG. 3—Profile 2, frequency distribution of the Foraminifera off Point Arguello.

explanation must be sought along other lines.

Abyssal zone.—This zone ranges downward from the 6000 foot depth (2000 meters). It is present only in the Point Arguello and San Francisco profiles. Upon the basis of information presented in figures 3 and 4 and in table I, there seems to be a rather well-defined subdivision of the abyssal zone at a depth of about 8000 feet. The upper subfacies is restricted to the 6000 to 8000 foot range and is characterized by the high frequency occurrence of *Uvigerina proboscidea, Uvigerina hispida, Bulimina barbata, Bulimina rostrata,* and by the shallowest occurrence of *Gyroidina gemma* and *Gyroidina soldanii.*

The lower subdivision of the abyssal zone extends downward from 8000 feet to the maximum depth considered in this investigation, nearly 12,000 feet. The lower subdivision is characterized by the high frequency occurrence of *Uvigerina senticosa* in association with the somewhat less abundant *Nonion pompilioides, Nonion barleeanus,* and *Hoglundina elegans.* This assemblage was also found in samples submitted to the writer by R. F. Dill which were taken from the sea floor off Monterey Canyon at a depth of about 2000 fathoms.

Bulimina rostrata and *Nonion pompilioides* have been reported as appearing between the depths of 4000 and 5000 feet off Panama and La Jolla, but the maximum frequency is not defined (Natland and Kuenen, 1951, p. 83). Because of the generalized nature of the present investigation, the exact upper limit of the distribution of these species is not known; however, there are definite trends which are demonstrable in the frequency graphs, figures 2–4. It should be noted that the high frequency range of *Nonion pompilioides* is deeper than that of *Bulimina rostrata,* a relationship which apparently does not occur in the areas of Natland's investigations (1933).

The temperature gradient in that part of the abyssal zone represented in the northern profiles ranges from 2.2° (6000 ft.) to 1.53°C. (11,760 ft.), whereas the oxygen content ranges from about 1.6 (6000 ft.) to 3.0 ml/l (11,760 ft.). The salinity varies from about 34.6 to 34.7 parts per thousand and is probably unimportant as a limiting factor. Whether the deeper species are restricted to their habitat by the increased oxygen content at greater depth, the lower temperature range or increase in nitrogen percentage is not determinable upon the basis of the facts of this investigation. Perhaps these deep-water Foraminifera are abundant at depth simply because most other species cannot endure the environmental conditions there. This would explain their occurrence in shallower waters and in other environments.

FIG. 3—Profile 2, frequency distribution of the Foraminifera off Point Arguello.

ECOLOGIC FACTORS

In an empirical assessment of this nature, variations of environmental factors are easily associated with high frequencies of some species, but the evidence is insufficient in many cases to clearly establish or define limiting factors. Depth is probably important only because other factors are directly associated with changes in depth. Temperature change is progressive to considerable depths and is undoubtedly important as a limiting factor, at least to many species. As reported by Said (1950) in his work on the Red Sea, changes in biofacies occur with depth under conditions of little temperature change. He considers the organic content, sediment size, and other factors to be the probable reasons for the zonation there. The oxygen content of water is a limiting factor only when reduced to a minimum as in closed basins, but is probably of little significance in the open ocean except, perhaps as in this study, at a depth of about 2000 feet where it approaches a minimum of 0.4 ml/l. Salinity is apparently of little importance in the open ocean because of its low range of variability; however, this factor is of course a very important factor in some nearshore areas.

R. F. Dill analyzed the sediments off Point Arguello and found that the percentages of organic carbon and nitrogen increased out to about station 9 near the outer end of that profile, and from there on out, the percentages decreased. He ascribed the outward increase to progressively less dilution by clastics (Dill, 1952). The abundant clastics alone do not explain completely why the Foraminifera were so rare in the shallowest sample, so rare that this station was not plotted in the frequency graphs.

Abundant clastics are added to shallow waters near the shore off the Louisiana coast in the Gulf of Mexico and Foraminifera are relatively abundant there (Bandy, in press). The absence of clastic sedimentation explains the extreme abundance of specimens in the lower neritic zone, especially off San Diego, and their relative abundance in somewhat deeper water is also to be expected.

Measurements of turbidity are not available, nor are readings of the many other environmental factors. The sedimentary analyses and submarine geology of the San Diego region may be consulted in Emery, Butcher, Gould and Shepard (1953). In general, it was noted that glauconite was common to abundant throughout the lower neritic zone, especially off San Diego. The glauconitic area off Point Arguello is located at greater depths in the middle bathyal zone.

CONCLUSIONS

1. Diagnostic species of high frequency were found to be generally restricted to various depth zones. These are:

A. Brackish (polyhaline) zone: *Rotalia beccarii*

B. Middle neritic zone (0–150 feet): *Buliminella elegantissima, Elphidium translucens, Nonionella miocenica* var. *stella* and allied species

C. Lower neritic zone (150–600 feet):
   a. Southern assemblage, *Cassidulina californica, Cassidulina limbata, Cassidulina quadrata, Cassidulina tortuosa,* etc.
   b. Northern assemblage, *Uvigerina hollicki, Uvigerina tenuistriata*—Cordell Bank, off San Francisco, *Cassidulina californica* var. and *Cassidulina limbata*

D. Bathyal zone (600–6000 feet):
   a. Southern assemblage, *Planulina ornata,* greater than 20 percent.
   b. Northern assemblage, *Uvigerina peregrina* and variations
      —Upper bathyal (600–1500 feet) *Angulogerina angulosa, Bolivina spissa*
      —Middle bathyal (1500–3000 feet) *Cassidulina delicata, Cassidulina cushmani, Epistominella pacifica, Epistominella smithi, Epistominella evax*
      —Lower bathyal (3000–6000 feet) *Bulimina striata* var. *mexicana, Cassidulina translucens, Cassidulina lomitensis*

E. Abyssal zone (below 6000 feet):
   a. Southern abyssal zone, not sampled
   b. Northern abyssal zone:
      —Upper abyssal (6000–8000 feet) *Uvigerina proboscidea, Uvigerina hispida, Bulimina rostrata, Bulimina barbata*
      —Lower abyssal (below 8000 feet) *Uvigerina senticosa, Nonion pompilioides*

EXPLANATION OF PLATE 23

FIGS. *1*—*Epistominella evax* Bandy, n. sp., ×73. *a*, dorsal view; *b*, apertural view; *c*, ventral view; holotype, USC No. 1044 (p. 179)

2—*Epistominella pacifica* (Cushman), ×50. *a*, dorsal view; *b*, apertural view; *c*, ventral view; hypotype, USC No. 3380. (p. 177)

3—*Eponides tener* (Brady), ×50. *a*, ventral view; *b*, apertural view; *c*, dorsal view; hypotype, USC No. 3383. (p. 177)

4—*Gyroidina gemma* Bandy, n. sp., ×50. *a*, dorsal view; *b*, apertural view; *c*, ventral view; holotype, USC No. 3045. (p. 179)

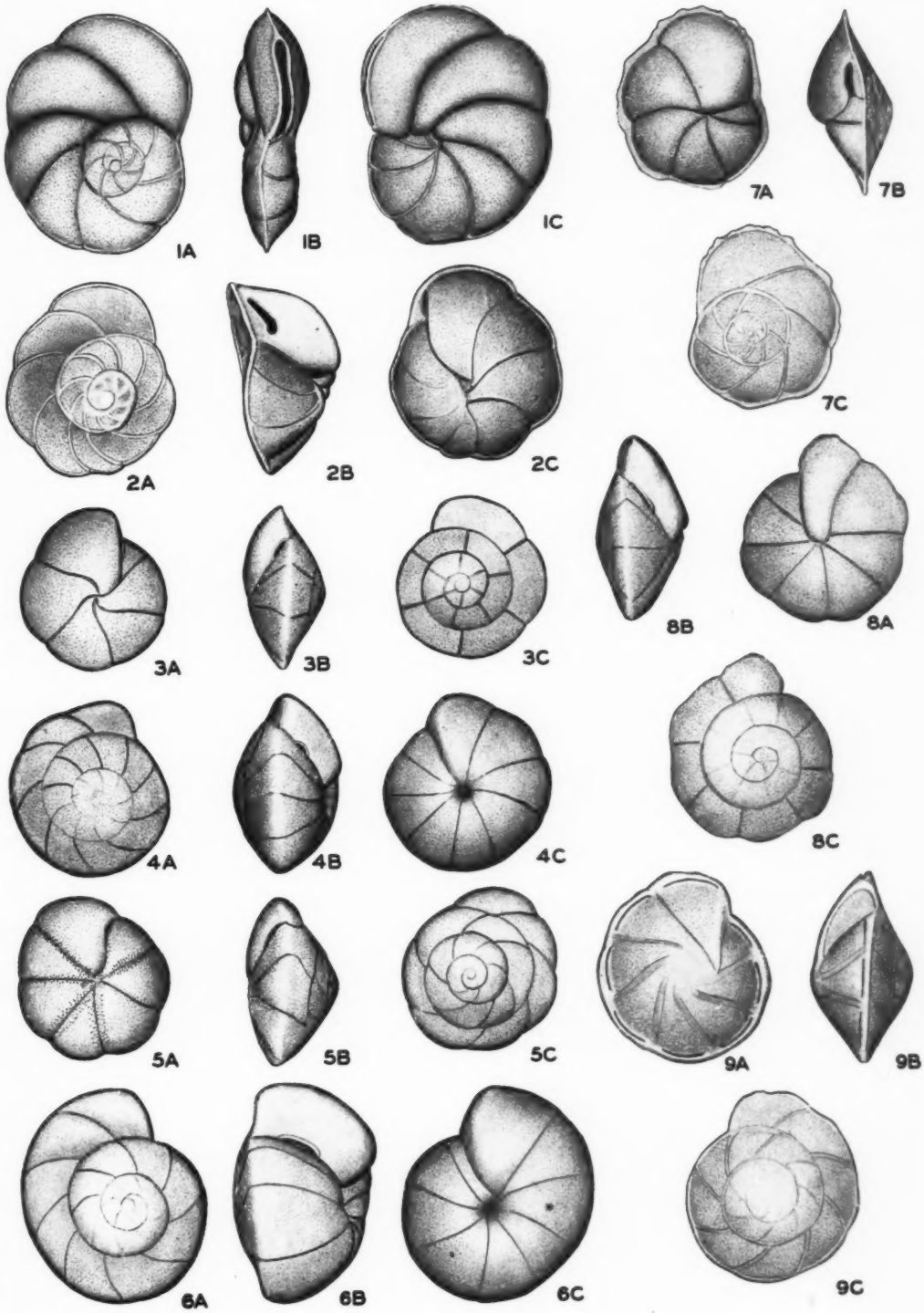
5—*Eponides frigidus* (Cushman), ×53. *a*, ventral view; *b*, apertural view; *c*, dorsal view; hypotype, USC No. 3364. (p. 177)

6—*Gyroidina soldanii* d'Orbigny, ×33. *a*, dorsal view; *b*, apertural view; *c*, ventral view; hypotype, USC No. 3384. (p. 177)

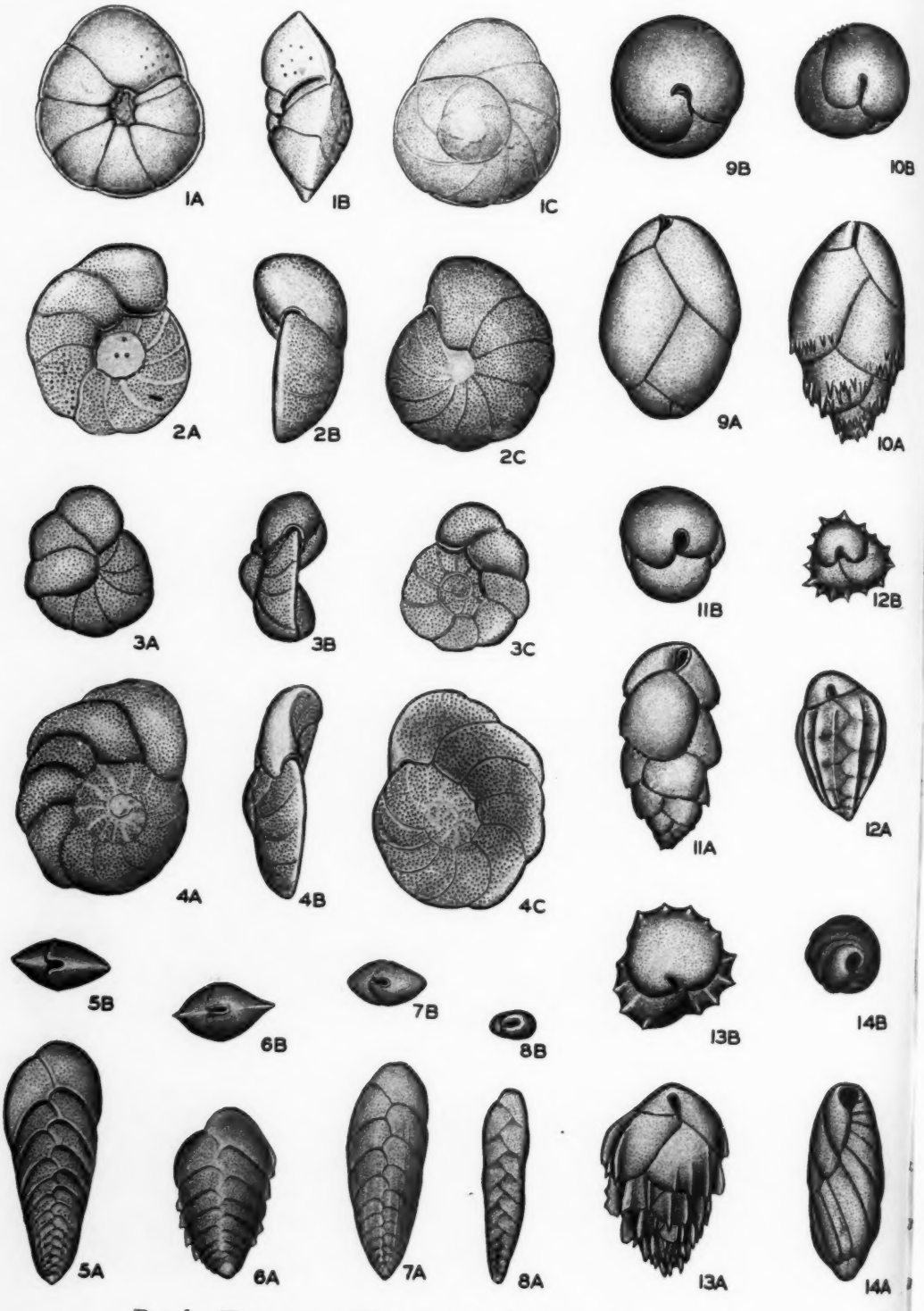
7—*Epistominella smithi* (R. E. and K. C. Stewart), ×70. *a*, ventral view; *b*, apertural view; *c*, dorsal view; hypotype, USC No. 3381. (p. 177)

8—*Eponides subtener* (Galloway and Wissler), ×50. *a*, ventral view; *b*, apertural view; *c*, dorsal view; hypotype, USC No. 3382. (p. 177)

9—*Hoglundina elegans* (d'Orbigny), ×33. *a*, ventral view; *b*, apertural view; *c*, dorsal view; hypotype, USC No. 3385. (p. 177)



Bandy, Frequency Distribution of Recent Foraminifera



Bandy, Frequency Distribution of Recent Foraminifera

2. Two major faunal gradations require explanation. The first is the bathymetric gradation in which temperature apparently plays the dominant role. It has been demonstrated in other studies that foraminiferal zonation exists in the absence of temperature gradation. This situation, in addition to the findings of the same shallow-water species in colder deeper habitats in the northern profiles than in the southern profile, suggests that other factors than temperature may be responsible for faunal variation. The oxygen content may be important as a limiting factor where it attains a minimum value at a depth of about 2000 feet, otherwise it is thought to be high enough to be noncritical in the open ocean. The total salinity variation in the open ocean areas was minor, ranging from about 33.2°/₀₀ to 34°/₀₀, and was therefore considered to be unimportant. In San Francisco Bay the salinity range was about 20°/₀₀ to 30°/₀₀ and a typical brackish fauna is developed there.

The second faunal gradation is that which varies with latitude. Temperature differences may explain the differences in the shallower-water faunas generally; however, the bathyal faunas below the thermocline are different in the northern and southern profiles even though the temperature differences are minor for equivalent depths in the respective areas. Either the extrapolated temperatures are in error, or other factors are responsible for the differences.

In the present investigation, the progressive decrease of temperature with depth is probably the controlling factor for many of the species; however, other factors also must play an important part in determining distributional patterns.

3. Evidence of displaced foraminiferal species may be seen in the outer end of profile 1, figure 2, wherein two of the shallow-water species make up important percentages of the benthonic population at the outer two stations. Suggestions of similar displacements may be observed in the other profiles.

4. The species of *Uvigerina* proved to be generally dependable zone determinants in the two northern profiles. The slender, more delicately costate species characterize the lower neritic zone, the more heavily costate

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EXPLANATION OF PLATE 24

FIGS. *1*—*Poroeponides cribrorepandus* Asano and Uchio, ×20. *a*, ventral view; *b*, apertural view; *c*, dorsal view; hypotype, USC No. 3404. (p. 177)

2—*Cibicides fletcheri* Galloway and Wissler, ×50. *a*, dorsal view; *b*, apertural view; *c*, ventral view; hypotype, USC no. 3402. (p. 176)

3—*Cibicides lobatus* (d'Orbigny), ×33. *a*, ventral view; *b*, apertural view; *c*, dorsal view; hypotype, USC No. 3361. (p. 176)

4—*Planulina ornata* (d'Orbigny), ×33. *a*, ventral view; *b*, apertural view; *c*, dorsal view; hypotype, USC No. 3390. (p. 177)

5—*Bolivina spissa* Cushman, ×50. *a*, side view; *b*, apertural view; hypotype, USC No. 3371. (p. 176)

6—*Bolivina acuminata* Natland, ×70. *a*, side view; *b*, apertural view; hypotype, USC No. 3396. (p. 176)

7—*Bolivina advena* Cushman var. *acutula* Bandy, n. var., ×70. *a*, side view; *b*, apertural view; holotype, USC No. 3048. (p. 180)

8—*Bolivina pacifica* Cushman and McCulloch, ×50. *a*, side view; *b*, apertural view; hypotype, USC No. 3356. (p. 176)

9—*Bulimina affinis* d'Orbigny, ×23. *a*, side view; *b*, apertural view; hypotype, USC No. 3357. (p. 176)

10—*Bulimina barbata* Cushman, ×50. *a*, side view; *b*, apertural view; hypotype, USC No. 3373. (p. 176)

11—*Bulimina denudata* Cushman and Parker, ×73. *a*, side view; *b*, apertural view; hypotype, USC No. 3398. (p. 176)

12—*Bulimina rostrata* H. B. Brady, ×73. *a*, side view; *b*, apertural view; hypotype, USC No. 3375. (p. 176)

13—*Bulimina striata* d'Orbigny var. *mexicana* Cushman, ×33. *a*, side view; *b*, apertural view; hypotype, USC No. 3372. (p. 176)

14—*Buliminella elegantissima* (d'Orbigny), ×70. *a*, side view; *b*, apertural view; hypotype, USC No. 3359. (p. 176)

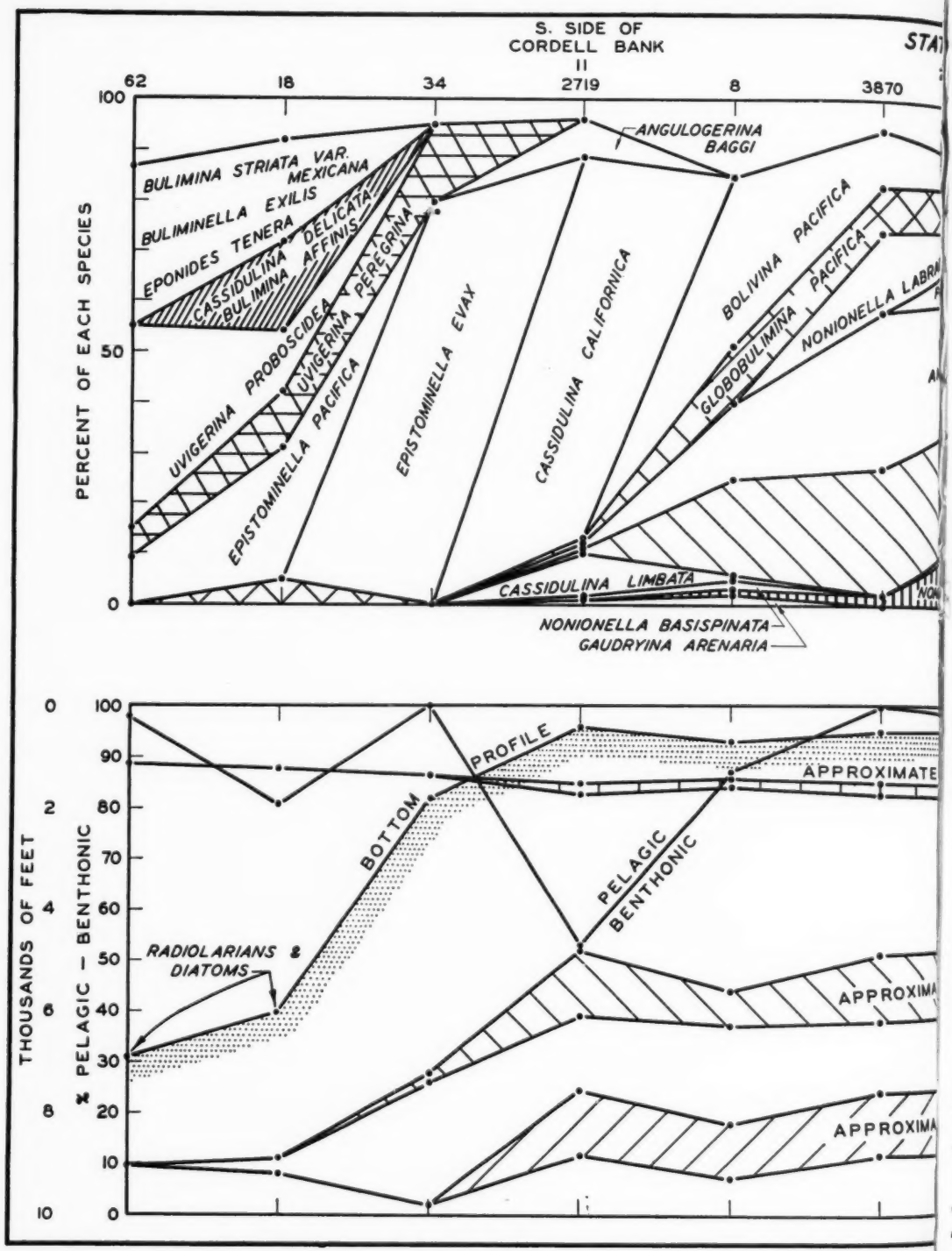
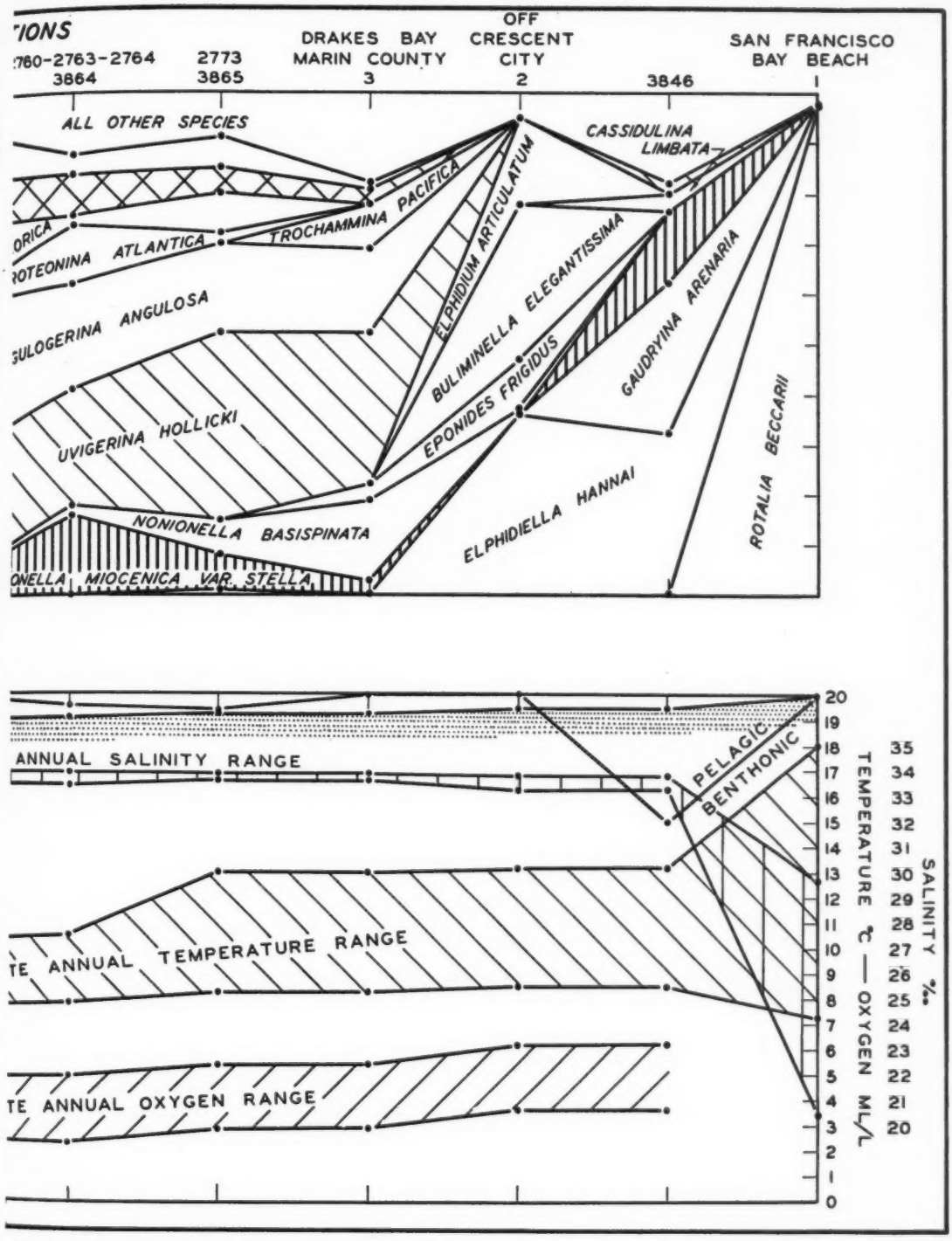


FIG. 4—Profile 3, frequency distribution



of the Foraminifera off San Francisco.

species occupy the bathyal zone, the hispid and spinose species are abundant in the upper abyssal zone and a finely papillate species is diagnostic of the lower abyssal zone.

FAUNAL REFERENCE LIST

Listed below are the species of Foraminifera used in making up the frequency profiles (figs. 2–4). After each species is given the original reference and another reference to the plate and figures in this paper.

Angulogerina angulosa (WILLIAMSON), 1858, On the Recent Foraminifera of Great Britain, Roy. Society, London, England, p. 67, pl. 5, fig. 140.
—— This paper, pl. 25, fig. 13.

Angulogerina baggi (GALLOWAY and WISSLER), 1927, Jour. Paleontology, vol. 1, p. 75, pl. 11, fig. 19.

Angulogerina hughesi (GALLOWAY and WISSLER), 1927, idem, p. 76, pl. 12, fig. 5.

Bolivina acuminata NATLAND, 1946, in Cushman and Gray, Cushman Lab. Foram. Res., Spec. Publ. 19, p. 34, pl. 5, fig. 46.
—— This paper, pl. 24, fig. 6.

Bolivina pacifica CUSHMAN and MCCULLOCH, 1942, Allan Hancock Pacific Expeditions, vol. 6, no. 4, p. 185, pl. 21, figs. 2, 3.
—— This paper, pl. 24, fig. 8.

Bolivina spissa CUSHMAN, 1926, Contr. Cushman Lab. Foram. Res., vol. 2, p. 45, pl. 6, figs. 8a, b.
—— This paper, pl. 24, fig. 5.

Bolivina advena Cushman var. *acutula* BANDY, n. var. This paper, p. 180, pl. 24, fig. 7.

Bulimina affinis D'ORBIGNY, 1840, in De la Sagra, Hist. Fis. Pol. Nat. Cuba, Foraminiferes, vol. 6, p. 109, pl. 2, figs. 25, 26.
—— This paper, pl. 24, fig. 9.

Bulimina barbata CUSHMAN, 1927, Scripps Inst. Oceanography Bull. Tech. Ser., vol. 1, no. 10, p. 151, pl. 2, fig. 11.
—— This paper, pl. 24, fig. 10.

Bulimina denudata CUSHMAN and PARKER, 1938, Contr. Cushman Lab. Foram. Res., vol. 14, p. 57, pl. 10, figs. 1, 2.
—— This paper, pl. 24, fig. 11.

Bulimina marginata D'ORBIGNY, 1826, Annales Sci. Nat., vol. 7, p. 269, no. 4, pl. 12, figs. 10–12. Specimens of this species may have been included in the preceding species in making the frequency counts.

Bulimina rostrata H. B. BRADY, 1884, *Challenger* Report, Zoology, vol. 9, p. 408, pl. 51, figs. 14, 15.
—— This paper, pl. 24, fig. 12.

Bulimina striata d'Orbigny var. *mexicana* CUSHMAN, 1922, U. S. Nat. Mus. Bull. 104, pt. 3, p. 95, pl. 21, fig. 2.
—— This paper, pl. 24, fig. 13.

Bulimina subacuminata CUSHMAN and R. E. STEWART, 1930, San Diego Soc. Nat. Hist. Trans., vol. 6, p. 65, pl. 5, figs. 2, 3a, b. Specimens of this species were relatively rare and very difficult to separate from the preceding species so that they were lumped together in the frequency counts.

Buliminella elegantissima (D'ORBIGNY), 1839, Voyage dans l'Amerique meridionale, vol. 5, pt. 5, Foraminiferes, p. 51, pl. 7, figs. 13, 14.
—— This paper, pl. 24, fig. 14.

Buliminella exilis (H. B. BRADY), 1884, *Challenger* Report, Zoology, vol. 9, p. 399, pl. 50, figs. 5, 6.
—— This paper, pl. 25, fig. 9.

Cassidulina californica CUSHMAN and HUGHES, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, no. 5, p. 12, pl. 2, fig. 1.
—— This paper, pl. 25, fig. 1; var. fig. 7.

Cassidulina cushmani R. E. and K. C. STEWART, 1930, Jour. Paleontology, vol. 4, p. 71, pl. 9, fig. 5. This species was rare compared to *C. delicata* and because the two occurred together, specimens of this species were included with the other species in the frequency counts.

Cassidulina delicata CUSHMAN, 1927, Scripps Inst. Oceanography Bull., Tech. Series, vol. 1, p. 168, pl. 6, fig. 5.
—— This paper, pl. 25, fig. 4.

Cassidulina limbata CUSHMAN and HUGHES, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, no. 5, p. 12, pl. 2, fig. 2.
—— This paper, pl. 25, fig. 2.

Cassidulina lomitensis GALLOWAY and WISSLER, 1927, Jour. Paleontology, vol. 1, p. 79, pl. 12, fig. 10.
—— This paper, pl. 25, fig. 5.

Cassidulina subglobosa H. B. Brady var. *quadrata* CUSHMAN and HUGHES, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, no. 5, p. 15, pl. 2, fig. 7.

Cassidulina tortuosa CUSHMAN and HUGHES, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, no. 5, p. 14, pl. 2, fig. 4.
—— This paper, pl. 25, fig. 3.

Cassidulina translucens CUSHMAN and HUGHES, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, no. 5, p. 15, pl. 2, fig. 5.
—— This paper, pl. 25, fig. 6.

Cibicidina basiloba (Cushman) var. *nitidula* BANDY, n. var. This paper, p. 178, pl. 22, fig. 3.

Cibicides fletcheri GALLOWAY and WISSLER, 1927, Jour. Paleontology, vol. 1, p. 64, pl. 10, figs. 8–9.
—— This paper, pl. 24, fig. 2.

Cibicides lobatus (D'ORBIGNY), 1839, in Barker, Webb, and Berthelot, Hist. Nat. Iles Canaries, vol. 2, pt. 2, Foraminiferes, p. 134, pl. 2, figs. 22–24.
—— This paper, pl. 24, fig. 3.

Elphidiella hannai (CUSHMAN and GRANT), 1927, Trans. San Diego Soc. Nat. Hist., vol. 5, p. 77, pl. 8, figs. 1, 2.
—— This paper, pl. 22, fig. 4.

Elphidium articulatum (D'ORBIGNY), 1839, Voyage dans l'Amerique meridionale, vol. 5, pt. 5, Foraminiferes, p. 30, pl. 3, figs. 9, 10.
—— This paper, pl. 22, fig. 5.

Elphidium translucens NATLAND, 1938, Scripps Inst. Oceanography Bull. Tech. ser., vol. 4, p. 144, pl. 5, figs. 3, 4.
—— This paper, pl. 22, fig. 9.

Epistominella evax BANDY, n. sp. This paper, p. 179, pl. 23, fig. 1.
Epistominella pacifica (CUSHMAN), 1927, Scripps Inst. Oceanography Bull. Tech. Ser., vol. 1, p. 165, pl. 5, figs. 14, 15.
—— This paper, pl. 23, fig. 2.
Epistominella smithi (R. E. and K. C. STEWART), 1930, Jour. Paleontology, vol. 4, p. 70, pl. 9, fig. 4.
—— This paper, pl. 23, fig. 7.
Eponides frigidus (CUSHMAN), 1922, Contr. Canadian Biol., no. 9, p. 144.
—— This paper, pl. 23, fig. 5.
Eponides subtener (GALLOWAY and WISSLER), 1927, Jour. Paleontology, vol. 1, p. 60, pl. 10, fig. 4.
—— This paper, pl. 23, fig. 8.
Eponides tener (BRADY), 1884, *Challenger* Report, Zoology, vol. 9, p. 665, pl. 95, fig. 11.
—— This paper, pl. 23, fig. 3.
Gaudryina arenaria GALLOWAY and WISSLER, 1927, Jour. Paleontology, vol. 1, p. 68, pl. 11, fig. 5.
—— This paper, pl. 21, fig. 9.
Globobulimina pacifica CUSHMAN, 1927, Contr. Cushman Lab. Foram. Res., vol. 3, p. 67, pl. 14, fig. 12.
Gyroidina gemma BANDY, n. sp., this paper, p. 179, pl. 23, fig. 4.
Gyroidina soldanii D'ORBIGNY, 1826, Ann. Sci. Nat. Paris, France, ser. 1, tome 7, p. 278, modeles no. 36.
—— This paper, pl. 23, fig. 6.
Hoglundina elegans (D'ORBIGNY), 1826, Ann. Sci. Nat., Paris, France, ser. 1, tome 7, p. 276.
—— This paper, pl. 23, fig. 9.
Nonion barleeanus (WILLIAMSON), 1858, Recent Foraminifera of Great Britain, p. 32, pl. 3, figs. 68, 69.
—— This paper, pl. 21, fig. 8.
Nonion pompilioides (FICHTEL and MOLL), 1798, Testacea microscopia, p. 31, pl. 2, figs. a–c.
—— This paper, pl. 21, fig. 12.
Nonionella basispinata (CUSHMAN and MOYER), 1930, Contr. Cushman Lab. Foram. Res., vol. 6, p. 54, pl. 7, figs. 18a, b.
—— This paper, pl. 21, fig. 13.
Nonionella labradorica (DAWSON), 1860, Canadian Naturalist, vol. 5, p. 191, fig. 4.
—— This paper, pl. 22, fig. 1.
Nonionella miocenica Cushman, var. *stella* CUSHMAN and MOYER, 1930, Contr. Cushman Lab. Foram. Res., vol. 6, p. 56, pl. 7, figs. 17a–c.
—— This paper, pl. 22, fig. 2.
Planulina ornata (D'ORBIGNY), 1839, Voyage dans l'Amerique meridionale, vol. 5, pt. 5, Foraminiferes, p. 40, pl. 6, figs. 7–9.
—— This paper, pl. 24, fig. 4.
Poroeponides cribrorepandus ASANO and UCHIO, 1951, Illustrated catalogue of Japanese Tertiary smaller Foraminifera, pt. 14, p. 18, figs. 134, 135.
—— This paper, pl. 24, fig. 1.
Proteonina atlantica CUSHMAN, 1944, Cushman Lab. Foram. Res., Spec. Pub. 12, p. 5, pl. 1, fig. 4.
—— This paper, pl. 21, fig. 5.
Pyrgo inornata (D'ORBIGNY), 1846, Foram. Foss. Vienne, p. 266, pl. 16, figs. 7–9.
—— This paper, pl. 21, fig. 6.
Quinqueloculina angulo-striata CUSHMAN and VALENTINE, 1930, Contr. Dept. Geology, Stanford University, vol. 1, no. 1, p. 12, pl. 2, fig. 5.
—— This paper, pl. 21, fig. 1.
Quinqueloculina lamarckiana D'ORBIGNY, 1839, in De la Sagra, Hist. Fis. Pol. Nat. Cuba, Foraminiferes, p. 189, pl. 11, figs. 14, 15.
—— This paper, pl. 21, fig. 3.
Rotalia beccarii (LINNAEUS), 1758, Syst. Nat., tomus 1, p. 710, pl. 19, figs. 1a–c.
—— This paper, pl. 22, fig. 8.
Rotalia lomaensis BANDY, n. sp., this paper, p. 179, pl. 22, fig. 6.
Rotalia versiformis BANDY, n. sp., this paper, p. 179, pl. 22, fig. 5.
Spiroloculina dentata CUSHMAN and TODD, 1944, Cushman Lab. Foram. Res., Spec. Pub. 11, p. 71, pl. 9, figs. 33, 34.
—— This paper, pl. 21, fig. 4.
Textularia conica D'ORBIGNY, 1839, in De la Sagra, Hist. Fis. Pol. Nat. Cuba, Foraminiferes, p. 143, vol. 8, pl. 1, figs. 19–20.
—— This paper, pl. 21, fig. 10.
Textularia foliacea HERON-ALLEN and EARLAND, 1915, Zool. Soc. London Trans., pt. II, vol. 20, pt. 17, p. 628, pl. 47, figs. 17–20.
—— This paper, pl. 21, fig. 11.
Triloculina inornata d'Orbigny var. *longidentata* BANDY, n. var. This paper, p. 178, pl. 21, fig. 2.
Trochammina pacifica CUSHMAN, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 2, p. 39, pl. 6, figs. 3a–c.
—— This paper, pl. 21, fig. 7.
Uvigerina hollicki THALMANN, 1950, Contr. Cushman Found. Foram. Res., vol. 1, pt. 3, p. 45.
—— This paper, pl. 25, fig. 8.
Uvigerina hispida SCHWAGER, 1866, Novara Exped., Geol. Theil, Bd. 2, Abt. 2, p. 249, pl. 7, fig. 95. (Novara Exped. 1857–1859). In the frequency counts this species was included with *U. proboscidea* inasmuch as the latter was so abundant.
Uvigerina peregrina CUSHMAN, 1923, U. S. Nat. Mus. Bull., no. 104, pt. 4, p. 166, pl. 42, figs. 7–10.
—— This paper, pl. 25, fig. 10.
Uvigerina proboscidea SCHWAGER, 1866, Novara Exped., Geol. Theil, Bd. 2, p. 250, pl. 7, fig. 96.
—— This paper, pl. 25, fig. 11.
Uvigerina senticosa CUSHMAN, 1927, Scripps Inst. Oceanography, Bull. Tech. Ser., vol. 1, p. 159, pl. 3, fig. 14.
—— This paper, pl. 25, fig. 12.
Uvigerina tenuistriata REUSS, 1870, K. Akad. Wiss. Wien, Mathe.-Naturw. Cl., Sitzber, Wien, Osterreich, Bd. 62, Abt. 1, p. 485, pl. 22, figs. 34–37. Slender specimens assignable to this species were counted in with *U. hollicki* inasmuch as the two forms appeared to occur together.

SYSTEMATIC PALEONTOLOGY

In making the frequency studies of the Recent Foraminifera off California, several

previously undescribed species and varieties were encountered. These new forms are described and figured herein. The type specimens are deposited in the paleontological collections at the University of Southern California (USC).

Family MILIOLIDAE d'Orbigny, 1839
Genus TRILOCULINA d'Orbigny, 1826
TRILOCULINA INORNATA d'Orbigny var. LONGIDENTATA Bandy, n. var.
Plate 21, fig. 2

Test elongate ovate, of moderate size for the genus, width about seven-tenths the length; chambers of nearly uniform diameter in the biloculine side view, the last chamber more abruptly curved toward the base in the triloculine side view; chambers subcircular to subangular in cross section, successive chambers enlarging regularly in size; sutures slightly depressed; apertural end with only a slight neck; aperture a high narrow opening or arch with a high narrow plate-like tooth which projects noticeably from the aperture. Length, 0.90 mm.; breadth, 0.74 mm.; thickness, 0.51 mm.

This variety differs from typical specimens of the species (d'Orbigny, 1846, Foram. Foss. Bass. Tert. Vienne) in having an elongate aperture with a long thin tooth which projects from the aperture slightly.

The type occurred in shallow water off the mouth of the Tijuana River, San Diego County, California.

Holotype.—USC No. 1042.

Family ROTALIIDAE Reuss, 1860
Genus CIBICIDINA Bandy, 1949

Cibicidina BANDY, 1949, Bull. Amer. Paleontology, vol. 32, no. 131, p. 91.
Discopulvinulina HOFKER, 1951, The Foraminifera of the Siboga Expedition, pt. 3, p. 488.

In the second reference above, the genus *Cibicidoides* Brotzen was confused with *Cibicidina* (*Discopulvinulina*). It should be pointed out that the genus *Cibicidoides* is biconvex and coarsely perforate whereas *Cibicidina* is finely perforate and planoconvex. Those species included in "*Discopulvinulina*" which are coarsely perforate with an umbilical plug belong in the genus *Rotorbinella* Bandy, (1944, Jour. Paleontology, vol. 18, p. 372), e.g., *Rotorbinella turbo* (d'Orbigny).

CIBICIDINA BASILOBA (Cushman) var. NITIDULA Bandy, n. var.
Plate 22, fig. 3

Test planoconvex, mostly involute, dorsal side flattened, ventral side moderately convex; edge angled but not keeled; periphery smooth in the early part, slightly lobate in the later part of the test; chambers about eight or ten in the last whorl, increasing rather rapidly in size; dorsal suture arcuate, radial, strongly limbate and flush with the surface; ventral sutures curved, limbate and raised slightly in the early part, flush or slightly depressed in the later portion of the test; aperture a low arched opening beginning near the edge on the ventral side, extending across the edge and under the dorsal flap of the last chamber. Diameter, 0.88 mm.; thickness, 0.26 mm.

This variety differs from typical examples of *C. basiloba* (Cushman) (1918, U. S. Geol. Survey Bull. 676, p. 64) in having broadly limbate dorsal sutures and little if any indication of reentrants along the dorsal sutures. This variety also has raised limbate sutures on the ventral side of the test.

The form figured by Marks from the Vienna Basin (1951, Contr. Cushman Found. Foram. Res., vol. 2, p. 72, pl. 8, fig. 9) as *Cibicides boueanus* (d'Orbigny) differs from d'Orbigny's type in that the type was both figured and described as being coarsely perforate whereas the figure of Marks appears to be a finely perforate species and similar to this new variety.

The types of this variety are from fairly shallow water off San Diego, California.

Holotype.—USC No. 1043.

Genus EPISTOMINELLA Husezima and Maruhasi

Pulvinulinella CUSHMAN, 1926, Contr. Cushman Lab. Foram. Res., vol. 2, pt. 3, p. 62, pl. 9, fig. 9. Not *Pulvinulinella* Eimer and Fichert, 1899, which embraced species that do not belong in Cushman's species.
Epistominella HUSEZIMA and MARUHASI, 1944, Jour. Sigenkagaku Kenkyusyo, vol. 1, no. 3, p. 397. Genoholotype *E. pulchella* Husezima and Maruhasi, idem. p. 398, pl. 34, figs. 10a–c.
Pseudoparrella CUSHMAN and TEN DAM, 1948, Contr. Cushman Lab. Foram. Res., vol. 24, p. 49.

From the figure and description of the genoholotype of *Epistominella* it appears

that the type species may be synonymous with *E. smithi* (R. E. and K. C. Stewart) (1930, Jour. Paleontology, vol. 4, p. 70).

EPISTOMINELLA EVAX Bandy, n. sp.
Plate 23, fig. 1

Test ovate in side view, rotaloid and compressed; periphery smooth in the early portion, moderately lobate in the later part of the test; edge acute with a very narrow carina; chambers six to eight in the final whorl, closely appressed in the early part of the test, slightly inflated in the later portion; sutures limbate and flush in the early part of the test, somewhat depressed in the later portion, arcuate and tangential dorsally, arcuate and more nearly radial ventrally; wall finely perforate, smooth; aperture elongate, parallel and adjacent to the edge on the ventral side of the terminal face of the last chamber, with a thin narrow lip surrounding the opening. Maximum diameter, 0.48 mm.; thickness, 0.11 mm.

This species differs from *E. bradyana* (Cushman) (1927, Bull. Scripps Inst. of Oceanography, vol. 1, no. 10, p. 165) in being much compressed, carinate, and in having chambers which enlarge more rapidly than in Cushman's species.

The type occurred in about 1800 feet of water off San Francisco, California.

Holotype.—USC No. 1044.

Genus GYROIDINA d'Orbigny, 1826
GYROIDINA GEMMA Bandy, n. sp.
Plate 23, fig. 4

Test unequally biconvex, deeply convex ventrally, moderately so dorsally; umbilicus moderately large; chambers about eight to eleven in the final whorl; dorsal sutures slightly curved and oblique, flush; ventral sutures straight, radial, flush with surface, narrow; surface smooth, wall finely perforate; aperture a small arched opening midway between the edge and the umbilicus. Diameter, 0.52 mm.; thickness, 0.30 mm.

The biconvexity of this species causes it to appear like *Eponides;* however, the deep ventral side and the character of the aperture are features of *Gyroidina.*

This species is much more compressed than *G. soldanii* d'Orbigny (1826, Tableau methodique, Ann. Sci. Nat. ser. 1, vol. 7, p. 278) and the dorsal sutures are more oblique. It differs from *G. soldanii* d'Orbigny var. *rotundimargo* R. E. and K. C. Stewart (1930, Jour. Paleontology, vol. 4, p. 68) in the oblique dorsal sutures, somewhat fewer chambers, and in the greater convexity of the dorsal side.

The type specimens are from deep water off Point Conception.

Holotype.—USC No. 3045.

Genus ROTALIA Lamarck, 1804
ROTALIA LOMAENSIS Bandy, n. sp.
Plate 22, fig. 6

Test subcircular in side view, dome-shaped in edge view, slightly convex ventrally, domal dorsally; edge angled; periphery entire or very slightly lobulate; chambers seven to nine in the final whorl, increasing slowly and gradually in size, not inflated; dorsal side transparent revealing the inner whorls, ventral side with a strong umbilical plug; dorsal sutures tangential to the spiral suture and slightly arcuate, flush and only slightly thickened if at all; ventral sutures very slightly depressed, limbate, nearly radial, slightly curved and with incipient reentrants; wall finely perforate and smooth; aperture an arched opening at the base of the septal face about midway between umbo and edge. Diameter, 0.29 mm.; thickness, 0.19 mm.

This species is similar to *R. turbinata* Cushman and Valentine (1930, Contr. Stanford Univ. Dept. Geol., vol. 1) in general shape but differs from that species in having little dorsal thickening, no pronounced keel, and in being finely perforate. *R. turbinata* should be placed in the genus *Rotorbinella* Bandy (1949, Jour. Paleontology, vol. 18, p. 372).

The type specimens occurred in very shallow water off San Diego, California.

Holotype.—USC No. 3046.

ROTALIA VERSIFORMIS Bandy, n. sp.
Plate 22, fig. 5.

Test unequally biconvex, dorsal side moderately convex, ventral side flat to slightly convex; edge subangular to abruptly rounded; chambers six to eight in final whorl enlarging gradually in size as added; dorsal spire somewhat obscured by thickening; dorsal sutures limbate and flush to

raised, slightly, arcuate, tangential to the edge; ventral sutures very slightly curved, nearly radial, flush in the early part, becoming slightly depressed in the later part of the final whorl; wall finely perforate, dorsal side with white limbate sutures, frequently somewhat raised; umbilicus with distinct boss and with projecting inner ends of chambers, sutural reentrants tend to develop in the last three or four chambers, aperture a low arched opening extending from near the edge into the umbilicus, with distinct upper lip. Maximum diameter, 0.28 mm.; thickness, 0.13 mm.

The individuals of this species exhibit considerable variation with respect to relative convexity and in the prominence of the limbations on the dorsal side.

R. versiformis is similar to *R. bassleri* Cushman and Cahill (1933, U. S. Geol. Survey Prof. Paper 175 A, p. 32); however, this new species differs in having raised limbate dorsal sutures and it exhibits a more rapid increase in the width of the whorls.

Holotype.—USC No. 3047.

Family HETEROHELICIDAE Cushman, 1927
Genus BOLIVINA d'Orbigny, 1839
BOLIVINA ADVENA Cushman var.
ACUTULA Bandy, n. var.
Plate 24, fig. 7

Bolivina advena Cushman var. *striatella*, CUSHMAN, 1937, Spec. Publ. 9, Cushman Lab. Foram. Res., p. 98, pl. 16, figs. 15–17; not pl. 10, fig. 22.

Bolivina advena Cushman var. *striatella* CUSHMAN and MCCULLOCH, 1942, Allan Hancock Pacific Expeditions, vol. 6, no. 4, p. 187, pl. 21, figs. 7–11.

Test elongate, about twice as long as broad, oblanceolate, elliptical in cross section; edge acute to subangular throughout; chambers appressed, about 10 to 13 pairs, the last three pairs making up half of the test; sutures flush or very slightly depressed, curved and tangential to the edge, making an angle of about 45 degrees with the edge of the test; wall finely perforate, with striae in the early portion of the test, later part smooth; aperture a narrow high slit bordered by a narrow lip. Length, 0.42 mm.; breadth, 0.16 mm.; thickness, 0.09 mm.

This variety differs from typical representatives of the species in having arcuate rather than sinuate sutures, a sharp rather than rounded edge, and in the possession of striae in the early portion of the test. The variety differs from *B. advena* Cushman var. *striatella* Cushman (1925, Contr. Cushman Lab. Foram. Res., vol. 1, p. 30, pl. 5, figs. 3a, b) in having arcuate rather than sinuate sutures and in possessing a sharp to subangular edge rather than a rounded edge.

The type occurred in shallow water off the mouth of the Tijuana River, San Diego County, California.

Holotype.—USC No. 3048.

SAMPLE LOCATIONS

The stations are arranged in order of increasing depth, the same sequence as in the profiles (figs. 2–4).

SAN DIEGO SAMPLE LOCATIONS

Sample no.	Latitude	Longitude
1301	32°38.7′	117°12.8′
642	32°35.7′	117°08.9′
1488	32°32′	117°09′
647	32°32.7′	117°09.7′
879	32°31.7′	117°10.6′
1346	32°33.1′	117°10.9′
1339	32°33.3′	117°11.9′
1198	32°25.6′	117°14.6′
1336	32°32.8′	117°12.4′
875	32°31.8′	117°12.6′
1479	32°33.3′	117°12.4′
1182	32°36.1′	117°14.5′
345	32°33.1′	117°13.4′
961	32°33.2′	117°15′
985	32°33.0′	117°15′
983	32°33′	117°15.4′
1279	32°33.8′	117°15.4′
817	32°33.0′	117°15.8′
960	32°32.7′	117°16.0′
1268	32°32.7′	117°16.7′
1179	32°33.2′	117°16.8′
1188	32°43.2′	117°19.0′
1269	32°32.8′	117°16.7′
1142	32°43.2′	117°19.2′
1143	32°32.8′	117°17.9′
1154	32°41.0′	117°21.1′
1180	32°33.3′	117°19.4′
1263	32°33.7′	117°20.0′
1261	32°33.5′	117°20.8′
1264	32°33.3′	117°21.0′
4	32°32.5′	117°21.3′
5	32°32.4′	117°22.3′
833	32°32.3′	117°22.1′
6	32°31.9′	117°23.1′
7	32°31.5′	117°24.3′
8	32°31.4′	117°25.5′

POINT ARGUELLO SAMPLE LOCATIONS

Sample no.	Latitude	Longitude
2	34°42′	120°45′
3	34°42′	120°50′
4	34°42′	120°55′
5	34°42′	120°57′
6	34°37′	121°09′
7	34°34′	121°17′
8	34°32′	121°24′
9	34°28′	121°33′
10	34°25′	121°37′
11	34°24′	121°39′

SAN FRANCISCO SAMPLE LOCATIONS

Sample no.	Latitude	Longitude
1	San Francisco Bay shore, Calif. Acad. Sci. 16443	
3846	38°50′	123°05.4′
2	Crescent City, Calif., 1 to 3 mi. off breakwater, Calif. Acad. Sci.	
3	Drakes Bay, Marin Co., Calif. Acad. Sci. 31110	
2773	38°07.7′	123°13.2′
3865	38°14.6′	123°14.8′
3864	38°13.8′	123°17′
2760	38°06.5′	123°15.2′
2763	38°02.6′	123°16′
2764	38°01.35′	123°16.3′
3870	38°06.8′	123°17.5′
8	38°07.5′	123°23.6′, Calif. Acad. Sci.
11	37°59.2′	123°27.0′, Calif. Acad. Sci.
2719	37°55.3′	123°20.2′
34	37°31.9′	123°02.8′, Calif. Acad. Sci.
18	38°02.5′	123°36.3′, Calif. Acad. Sci.
62	37°42.5′	123°23.0′, Calif. Acad. Sci.

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EXPLANATION OF PLATE 25

FIGS. *1*—*Cassidulina californica* Cushman and Hughes, ×33. *a*, side view; *b*, apertural view; *c*, opposite side; hypotype, USC No. 3399. (p. 176)

2—*Cassidulina limbata* Cushman and Hughes, ×50. *a*, side view; *b*, apertural view; *c*, opposite side; hypotype, USC No. 3377. (p. 176)

3—*Cassidulina tortuosa* Cushman and Hughes, ×50. *a*, side view; *b*, apertural view; *c*, opposite side; hypotype, USC No. 3400. (p. 176)

4—*Cassidulina delicata* Cushman, ×70. *a*, side view; *b*, apertural view; *c*, opposite side; hypotype, USC No. 3376. (p. 176)

5—*Cassidulina lomitensis* Galloway and Wissler, ×33. *a*, side view; *b*, apertural view; *c*, opposite side; hypotype, USC No. 3378. (p. 176)

6—*Cassidulina translucens* Cushman and Hughes, ×33. *a*, side view; *b*, apertural view; *c*, opposite side; hypotype, USC No. 3379. (p. 176)

7—*Cassidulina californica* Cushman and Hughes var., ×23. *a*, side view; *b*, apertural view; hypotype, USC No. 3360. (p. 176)

8—*Uvigerina hollicki* Thalmann, ×50. *a*, side view; *b*, apertural view; hypotype, USC No. 3391. (p. 177)

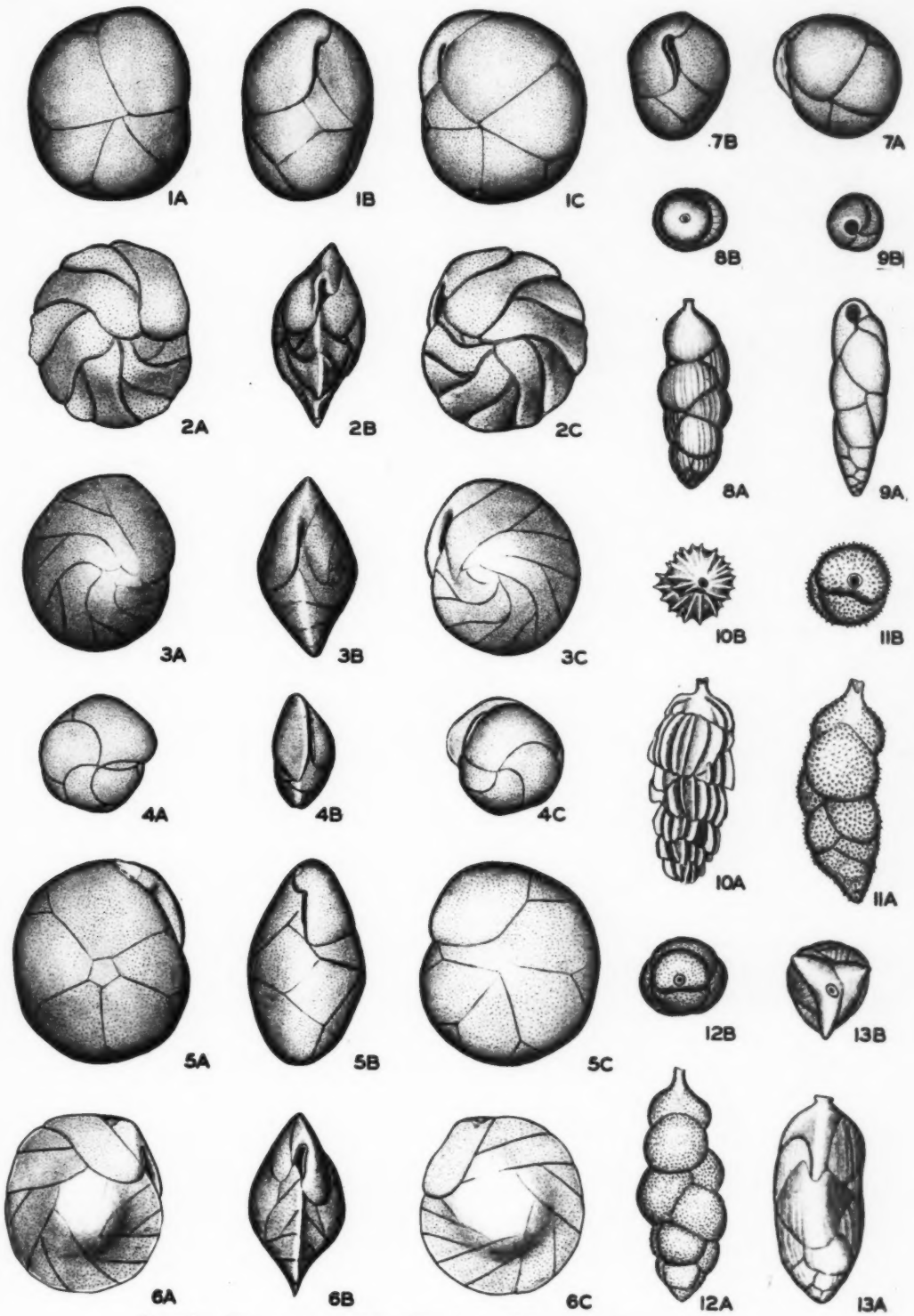
9—*Buliminella exilis* (H. B. Brady), ×53. *a*, side view; *b*, apertural view; hypotype, USC No. 3358. (p. 176)

10—*Uvigerina peregrina* Cushman, ×33. *a*, side view; *b*, apertural view; hypotype, USC No. 3392. (p. 177)

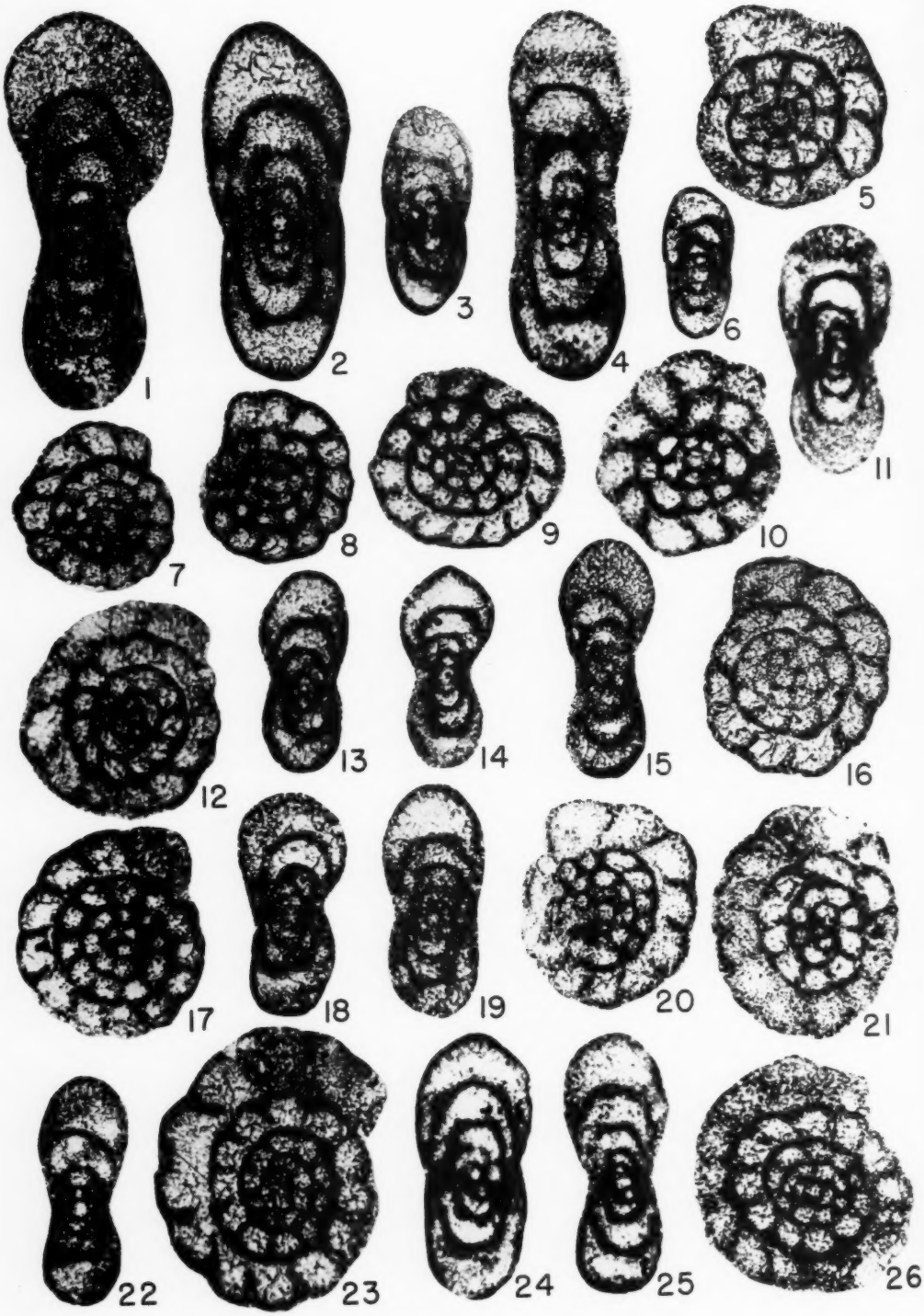
11—*Uvigerina proboscidea* Schwager, ×33. *a*, side view; *b*, apertural view; hypotype, USC No. 3393. (p. 177)

12—*Uvigerina senticosa* Cushman, ×33. *a*, side view; *b*, apertural view; hypotype, USC No. 3394. (p. 177)

13—*Angulogerina angulosa* (Williamson), ×70. *a*, side view; *b*, apertural view; hypotype; USC No. 3395. (p. 176)



Bandy, Frequency Distribution of Recent Foraminifera



Zeller, Upper Mississippian Foraminifera

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ENDOTHYROID FORAMINIFERA AND ANCESTRAL FUSULINIDS FROM THE TYPE CHESTERAN (UPPER MISSISSIPPIAN)

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ABSTRACT—Thin sections of limestone samples from the type sections of the Chesteran reveal the presence of the genus *Millerella* as far down in the Mississippian as the Paint Creek and Glen Dean formations (New Design group). These forms are small, partially evolute, and thin-walled. They possess small proloculi and have very weak secondary deposits. Along with these planispiral forms occur large plectogyroids. They are characterized by a high degree of angular distortion, rather massive secondary deposits, and some show well-developed nodes and hooks. Correlation of Chesteran limestones is believed possible with the aid of these foraminifers. Many forms are sufficiently distinctive in their morphology and phylogeny that they are readily distinguishable and appear to be restricted to a narrow stratigraphic range within the Chesteran.

COLLECTIONS

COLLECTIONS were obtained from the type section of the Renault formation from beds in Monroe County, Illinois, in the NW¼ Sec. 25., T. 4 S., R. 9 W., and the SW¼ Sec. 13, T. 4 S., R. 9 W. No endothyroids were found in any of the samples from this locality. Megafossils present in the Renault formation are *Talarocrinus*, *Archimedes*, *Lyropora*, *Pentremites*, and *Spirifer*. In addition, beds of supposed, Renault age were sampled at Walche's Cut 4 miles southeast of Princeton, Kentucky, along the Memphis and Louisville Railroad. Endothyroids were found in this sample.

The type section of the Paint Creek formation is in Randolph County, Illinois, along the tributaries of Paint Creek, 1.4 miles southwest of the town of Modoc. Since the type section is quite poorly exposed, a second more nearly complete section (Paint Creek No. 2) was also sampled 1.5 miles southeast of Modoc. Both sections yielded endothyroids in abundance. Megafossils present in this formation are *Chonetes*, *Spirifer*, *Composita*, *Eumetria*, *Linoproductus*, *Pterotocrinus*, *Archimedes*, and *Rhombopora*.

Samples were obtained from the type section of the Golconda formation in an exposure along the Ohio River bluff in Pope County, Illinois, 0.5 mile east of Rock

EXPLANATION OF PLATE 26

All illustrations on this plate are unretouched photomicrographs.

FIGS. *1–4, 6—Millerella designata* D. Zeller, n. sp. Axial sections showing the very slight degree of asymmetry in coiling, the presence of thin secondary deposits, and degree of umbilication, ×100. Fig. *2* is the holotype. *1, 4* are paratypes. Clore limestone, type, sample 1. (p. 194)

5—Millerella designata D. Zeller, n. sp. Sagittal section showing manner of coiling and attitude of septa, ×100. Clore limestone, type, sample 2. (p. 194)

7–10, 12, 16, 17, 20, 21, 23, 26—Millerella tortula D. Zeller, n. sp. Sagittal sections showing degree of umbilication, almost planispiral manner of coiling, thin walls, and low secondary deposits, ×100. Fig. *16* is the holotype. *10, 16, 20, 23*, Glen Dean limestone, type, sample 1; *7, 8, 9, 12, 17, 21, 26*, Glen Dean limestone, type, sample 4. (p. 192)

11—Millerella sp. Axial section showing good development of chomata and regular manner of coiling, ×100. Menard limestone, type, sample 19.

13–15, 18, 19, 24, 25—Millerella tortula D. Zeller, n. sp. Axial sections showing degree of umbilication, very slight asymmetry of coiling, and secondary deposits, ×100. *13, 14, 15, 19*, Glen Dean limestone, type, sample 1; *18, 24, 25*, Glen Dean limestone, type, sample 4. (p. 192)

22—Millerella ? sp. Axial section showing almost planispiral coiling, ×100. Paint Creek limestone, Sec. no. 2, sample 12.

FIG. *1*—Location map.

Quarry School in the SE¼ SE¼ Sec. 5, T. 13 S., R. 7 E. No endothyroids were found. Megafossils found in this formation are *Pterotocrinus* and *Pentremites*.

Samples of the Glen Dean limestone were obtained from the type area near the town of Glen Dean, Breckinridge County, Kentucky, in a small quarry northwest of the town and along an abandoned railroad which is the present road to Glen Dean. Endothyroids are abundant. Megafossils found in the Glen Dean limestone are *Archimedes*, *Pentremites*, *Cleiothyridina Fenestrellina*, *Prismopora*, and *Tholocrinus*.

Three limestone samples were collected from the type section of the Vienna limestone in Johnson County, Illinois, about 0.2 mile west of the town of Vienna in Sec. 5, T. 13 S., R. 3 E., in an old, almost obliterated quarry in which the shales were covered and overgrown with grass. A few specimens of *Plectogyra* were found in these samples.

Samples were collected from the type section of the Menard limestone in Randolph County, Illinois, in the NW¼ SW¼ Sec. 13, T. 7 S., R. 7 W., at the north end of the Chester bridge on Illinois State Highway 150, near the town of Menard. Endothyroids are present. The megafauna of the Menard limestone contains *Cleiothyridina*, *Spirifer*, *Pentremites*, *Diaphragmus*, *Eumetria*, *Orthotetes*, and *Dictyoclostus*.

The type section of the Clore limestone is in Randolph County, Illinois, in a gully in the SE¼ SE¼ SE¼ Sec. 20, T. 7 S., R. 6 W., just southwest of Clore School. Only one or two pieces of limestone were obtained here because the section is not sufficiently exposed to be measured in detail. Another section of Clore limestone was measured and collected at an abandoned W.P.A. quarry just southwest of Ford Station (Clore No. 2), in the SE¼ Sec. 33, T. 7 S., R. 6 W., about 1.5 miles southwest of Clore School. Endothyroids are abundant. Megafossils in this formation are *Composita*, *Pentremites*, *Spirifer*, *Batostomella*, *Cleiothyridina*, and *Orthotetes*.

Samples were obtained from the type section of the Kinkaid limestone in Jackson County, Illinois, along Kinkaid Creek in Sec. 6, T. 8 S., R. 4 W. These samples yielded abundant endothyroids. The megafauna includes *Fenestrellina*, *Archimedes*, *Pentremites*, *Composita*, *Bellerophon*, *Diaphragmus*, and *Cleiothyridina*.

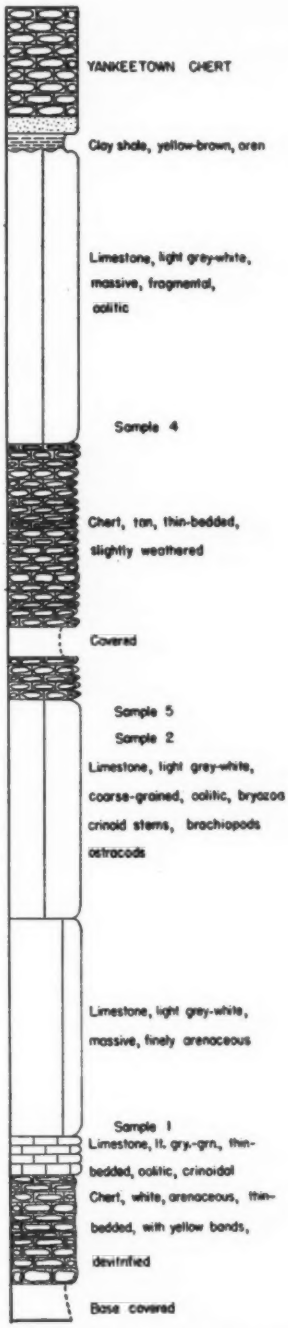
YANKEETOWN CHERT
Clay shale, yellow-brown, oren
Limestone, light grey-white, massive, fragmental, oolitic
Sample 4
Chert, tan, thin-bedded, slightly weathered
Covered
Sample 5
Sample 2
Limestone, light grey-white, coarse-grained, oolitic, bryozoa crinoid stems, brachiopods ostracods
Limestone, light grey-white, massive, finely arenaceous
Sample 1
Limestone, lt. gry.-grn., thin-bedded, oolitic, crinoidal
Chert, white, arenaceous, thin-bedded, with yellow bands, devitrified
Base covered

FIG. 2—Renault formation, type.

MORPHOLOGY

Renault forms.—The only endothyroids found in the Renault formation are large plectogyroids. They are thick-walled and possess moderately heavy secondary deposits consisting of hooks and low nodes and continuous filling on the floor of the chambers. The septa are long and curve down from the outer wall at nearly right angles. The proloculus is large. In forms where it is visible, the aperture is one-third the height of the last chamber.

Paint Creek forms.—Endothyroid foraminifers are abundant in the Paint Creek formation and it is these beds which mark the lowermost stratigraphic range of the truly planispiral forms. Specimens show a gradation from strongly plectogyroid forms with heavy secondary deposits to more nearly planispiral forms with little or no secondary deposits. In *Plectogyra*, the wall is thick and the septa are directed toward the anterior to a greater degree than in the specimens in the Renault below. The chambers are more highly swollen between the sutures than those in similar forms in the Renault formation. The degree of rotational distortion is slightly less in the Paint Creek plectogyroids than it is in the Renault plectogyroids; the proloculus size is smaller and the secondary deposits are not as heavy.

The planispiral form in the Paint Creek thin-sections is represented only by an axial section. It shows very slight asymmetry, is small in size, has thin walls, and resembles forms which appear in abundance higher in the section.

Golconda forms.—No endothyroids were found in the thin-sections prepared from samples collected at the type section of the Golconda formation.

Glen Dean forms.—The earliest of the truly planispiral forms which are here assigned to the genus *Millerella* appear in great abundance in the Glen Dean limestone. These planispiral forms are smaller than the plectogyroids with which they are associated. Many show very slight angular distortion with the addition of successive volutions. The number of chambers per volution is less than in any of the previously described species of *Millerella*. All of the Pennsylvanian species of *Millerella* are larger than the Glen Dean forms. The wall thickness is also greater in proportion to size of test in the Glen Dean forms than in those

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EXPLANATION OF PLATE 27

All illustrations on this plate are unretouched photomicrographs.

All the specimens of *Millerella* are illustrated ×100; all the specimens of *Plectogyra* are illustrated ×75.

FIGS. *1, 5, 7, 11*—*Millerella cooperi* D. Zeller, n. sp. Sagittal sections showing slightly plectogyroid juvenaria, attitude of septa, and manner of coiling, ×100. *5*, Kinkaid limestone, type, sample 30; *1, 7, 11*, Kinkaid limestone, type, sample 26. (p. 194)

2–4, 6, 8–10—*Millerella cooperi* D. Zeller, n. sp. Axial sections showing lenticular shape of the shell, large proloculus, planispiral manner of coiling, and presence of secondary deposits on the spirotheca, ×100. Fig. *6* is the holotype. *2, 9*, Kinkaid limestone, type, sample 26; *3, 4, 6*, Kinkaid limestone, type, sample 31; *8, 10*, Kinkaid limestone, type, sample 27. (p. 194)

12—*Plectogyra* sp. Vertical axial section showing plectogyroid manner of coiling and heavy secondary deposits, ×75. Vienna limestone, type, sample 42.

13—*Plectogyra* sp. Horizontal axial section showing prominent hooks rising from secondary deposits, ×75. Glen Dean limestone, type, sample 1.

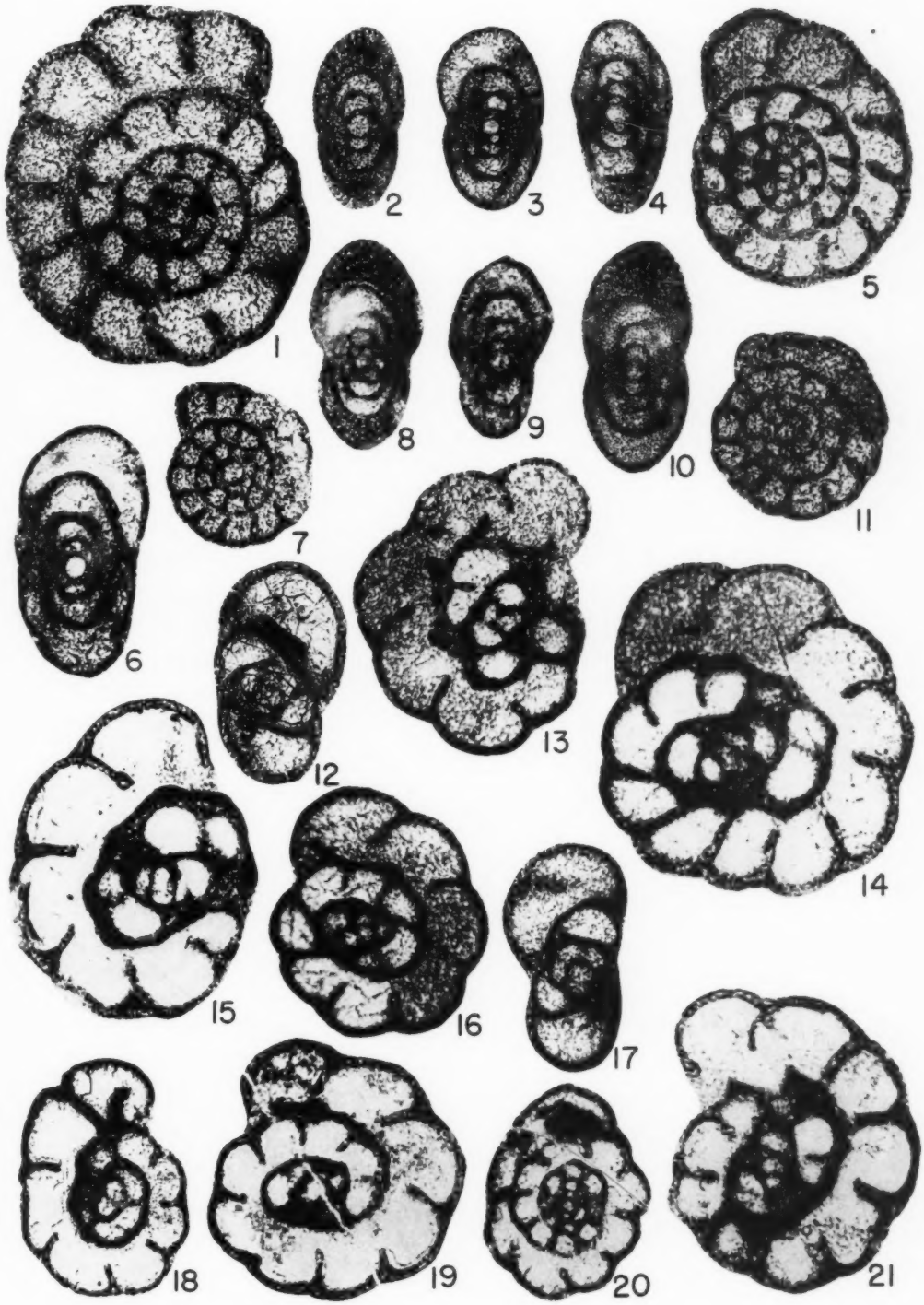
14, 16—*Plectogyra tantala* D. Zeller, n. sp. Horizontal axial sections showing attitude of septa and mode of coiling, ×75. Fig. *16* is the holotype. Paint Creek limestone, Sec. no. 2, sample 11. (p. 195)

15—*Plectogyra* sp. Horizontal axial section showing high aperture, attitude of septa, plectogyroid coiling, and heavy secondary deposits, ×75. Vienna limestone, type, sample 42.

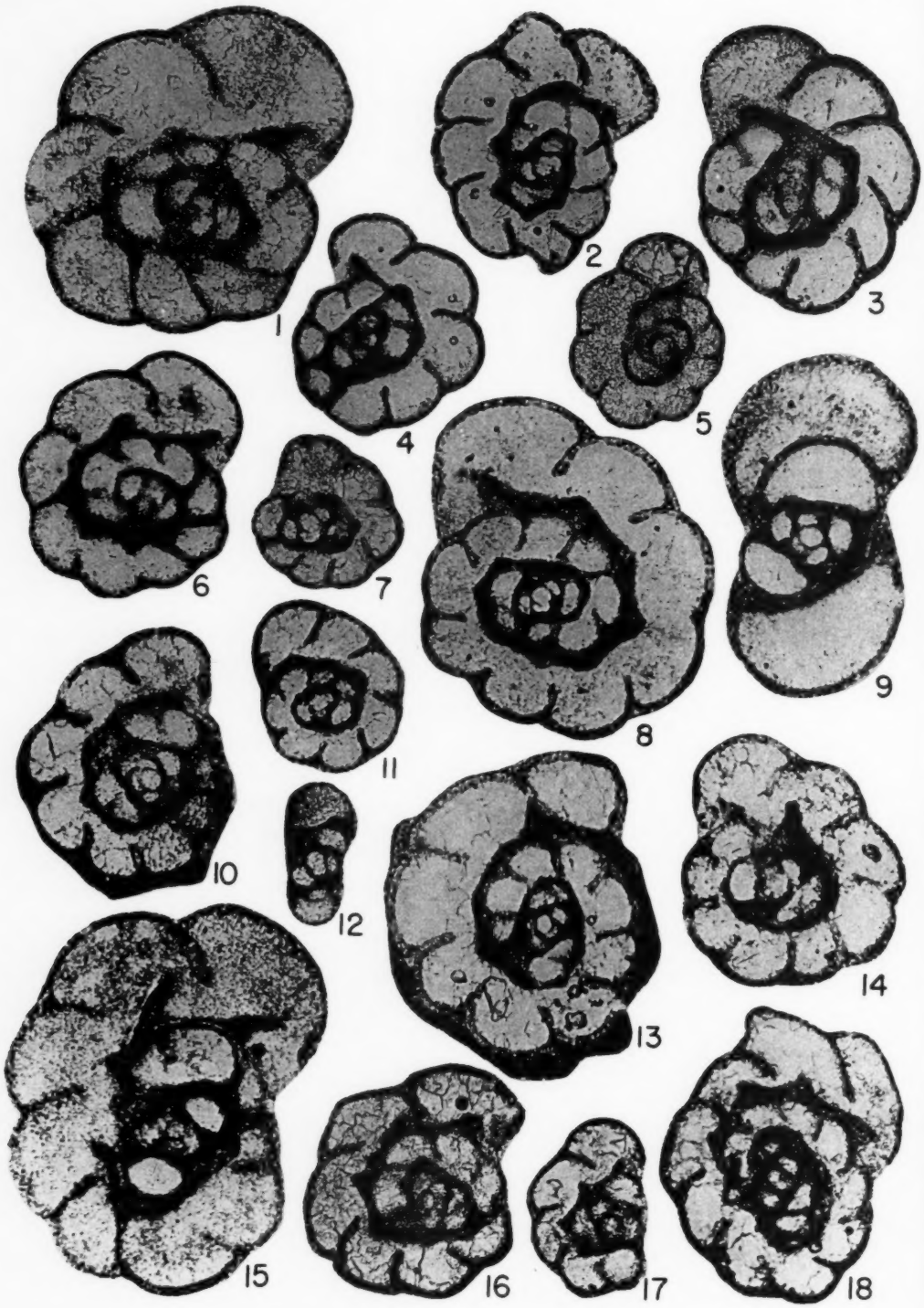
17—*Plectogyra tantala* D. Zeller, n. sp. Vertical axial section showing plectogyroid manner of coiling, ×75. Fig. *17* is a paratype. Paint Creek limestone, Sec. no. 2, sample 11. (p. 195)

18, 19, 21—*Plectogyra* sp. Horizontal axial section showing secondary deposits and hooks, ×75. Renault formation, Walche's Cut, Kentucky, sample 4.

20—*Plectogyra* sp. Horizontal axial section showing endothyroid coiling and lack of secondary deposits, ×75. Paint Creek limestone, Sec. no. 2, sample 12.



Zeller, Upper Mississippian Foraminifera



Zeller, Upper Mississippian Foraminifera

of the Pennsylvanian. The proloculus is very small and many specimens exhibit plectogyroid coiling in the juvenile part of the shell. The mode of coiling of many of these forms gives them a greater width in one direction than in the other. The axial sections indicate that most of the forms are umbilicate and evolute; the inner volutions are completely involute, but the outer one or two volutions become evolute. Often, the final chamber is distorted or crushed. Chomata are distinct in these forms.

The plectogyroids are large. They show well-developed secondary deposits with hooks, strongly developed nodes, and fairly thick deposits on the spirotheca. The walls are moderately thick and finely granular. The chambers are swollen between the sutures and the septa are anteriorly directed. Two species are recognized from this formation, *Plectogyra versabilis* Zeller, n. sp., and *P. kentuckyensis* Zeller, n. sp. *P. versabilis* is characterized by a more elongate axis of coiling and by the lumpy, irregular growth of the individual chambers. The wall is always very thin in the final two chambers. *P. kentuckyensis* is characterized by its more regular manner of coiling, its uniform addition of chambers, and the regular attitude of its septa. Its chambers are not highly inflated.

Vienna forms.—Very few specimens were obtained from the Vienna limestone owing to silicification and replacement of the limestone in the type section. Large plectogyroids are present. Their walls have great thickness, some of which may be accounted for by the addition of secondary calcite. Secondary deposits are moderately developed and continuous, but no prominent

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EXPLANATION OF PLATE 28

All illustrations on this plate are unretouched photomicrographs.

FIGS. *1, 4, 6—Plectogyra phrissa*, D. Zeller, n. sp. Horizontal axial section showing granular nature of wall, heavy secondary deposits, with sharp hooks, and chambers which are swollen between the sutures, ×75. Fig. *1* is the holotype. Kinkaid limestone, type, sample 30. (p. 198)

2—Plectogyra versabilis D. Zeller, n. sp. Horizontal axial section showing irregular manner of growth with uneven, lumpy chambers, and heavy secondary deposits, ×75. Paratype. Kinkaid limestone, type, sample 31. (p. 196)

3—Plectogyra sp. Horizontal axial section showing heavy secondary deposits, anteriorly directed septa, and high aperture, ×75. Kinkaid limestone, type, sample 31.

5—Plectogyra sp. Horizontal axial section showing almost regular manner of coiling, ×75. Kinkaid limestone, type, sample 30.

7, 10—Plectogyra pandorae D. Zeller, n. sp. Horizontal axial section showing manner of coiling, low secondary deposits, and absence of hooks and nodes, ×75. Fig. *10* is a paratype. Clore limestone, type, sample 1. (p. 196)

8—Plectogyra excellens D. Zeller, n. sp. Perfect horizontal axial section showing low degree of plectogyroid coiling, massive secondary deposits on spirotheca, and nature of joining of septa, ×75. Holotype. Clore limestone, type, sample 1. (p. 198)

9—Plectogyra excellens D. Zeller, n. sp. Vertical axial section showing large size, secondary deposits, and plectogyroid manner of coiling, ×75. Paratype. Clore limestone, type, sample 2. (p. 198)

11—Plectogyra sp. Horizontal axial section showing very slight plectogyroid coiling, ×75. Clore limestone, type, sample 1.

12—Plectogyra sp. Vertical axial section showing plectogyroid manner of coiling, ×75. Clore limestone, type, sample 4.

13, 14—Plectogyra pandorae D. Zeller, n. sp. Horizontal axial sections showing plectogyroid coiling and heavy secondary deposits in last chamber, ×75. Fig. *13* is the holotype. Menard limestone, type, sample 20. (p. 196)

15—Plectogyra maxima D. Zeller, n. sp. Horizontal axial section showing large hooks, high aperture, secondarily enlarged septa, and extreme size of test, ×75. Holotype. Menard limestone, type, sample 19. (p. 198)

16, 17—Plectogyra kentuckyensis D. Zeller, n. sp. Horizontal axial sections showing heavy secondary deposits, smooth addition of chambers, and plectogyroid manner of coiling, ×75. Fig. *16* is the holotype. Glen Dean limestone, type, sample 1. (p. 196)

18—Plectogyra versabilis D. Zeller, n. sp. Horizontal axial section showing irregular manner of growth with uneven, lumpy chambers, and heavy secondary deposits, ×75. Holotype. Glen Dean limestone, type, sample 1. (p. 196)

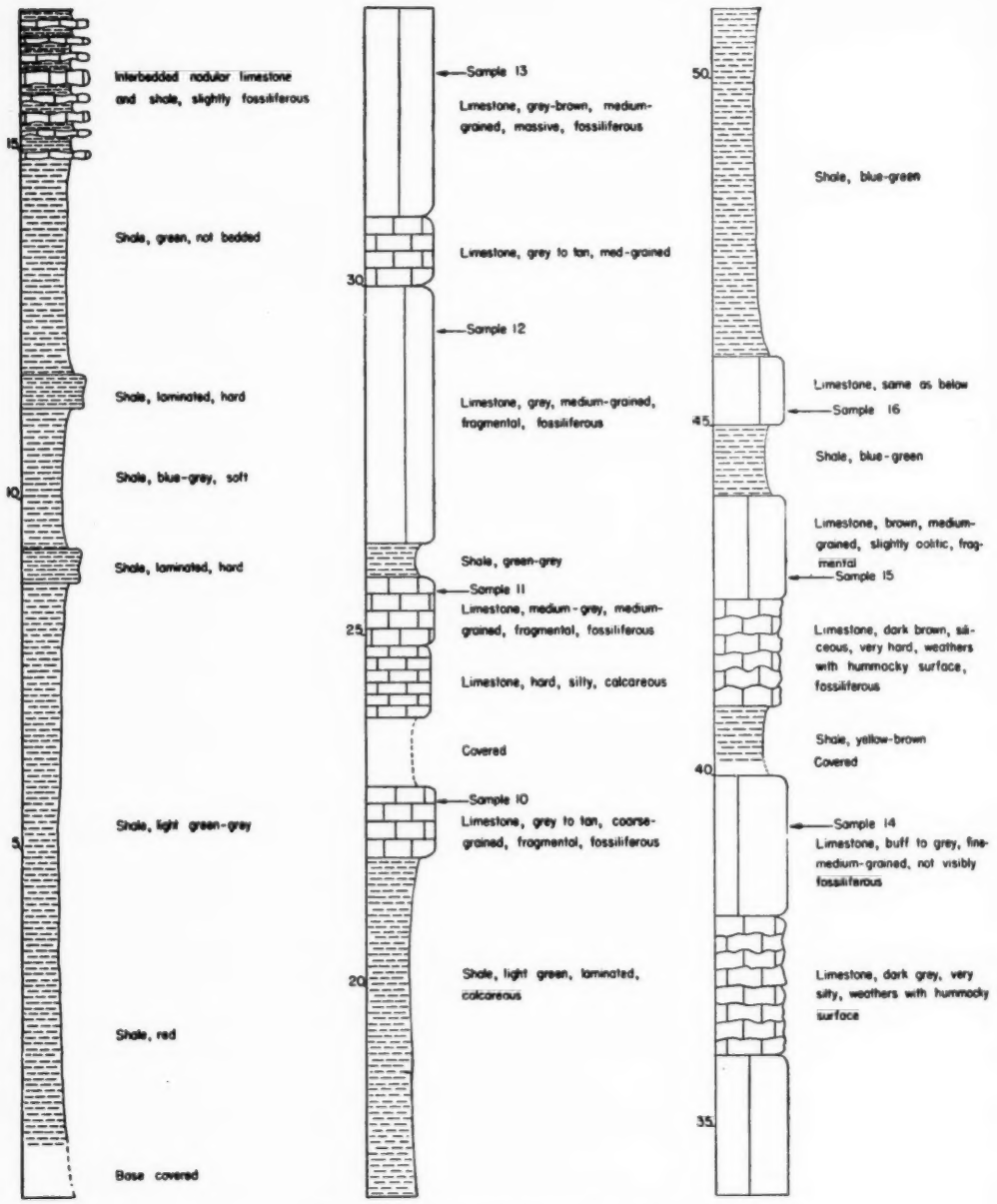

FIG. 3—Paint Creek formation, no. 2.

hooks or nodes were seen. The chambers are only slightly inflated between the sutures. The septa are anteriorly directed. The height of the aperture is one-fourth the height of the last chamber.

Menard forms.—The plectogyroids found in the Menard limestone are very large. They show varying degrees of development of secondary deposits and in wall thickness. Two distinct species are here recognized, *Plectogyra maxima* Zeller, n. sp., and *P. pandorae* Zeller, n. sp. *P. maxima* is distinguished by its extreme size, very strongly developed secondary deposits, and septa

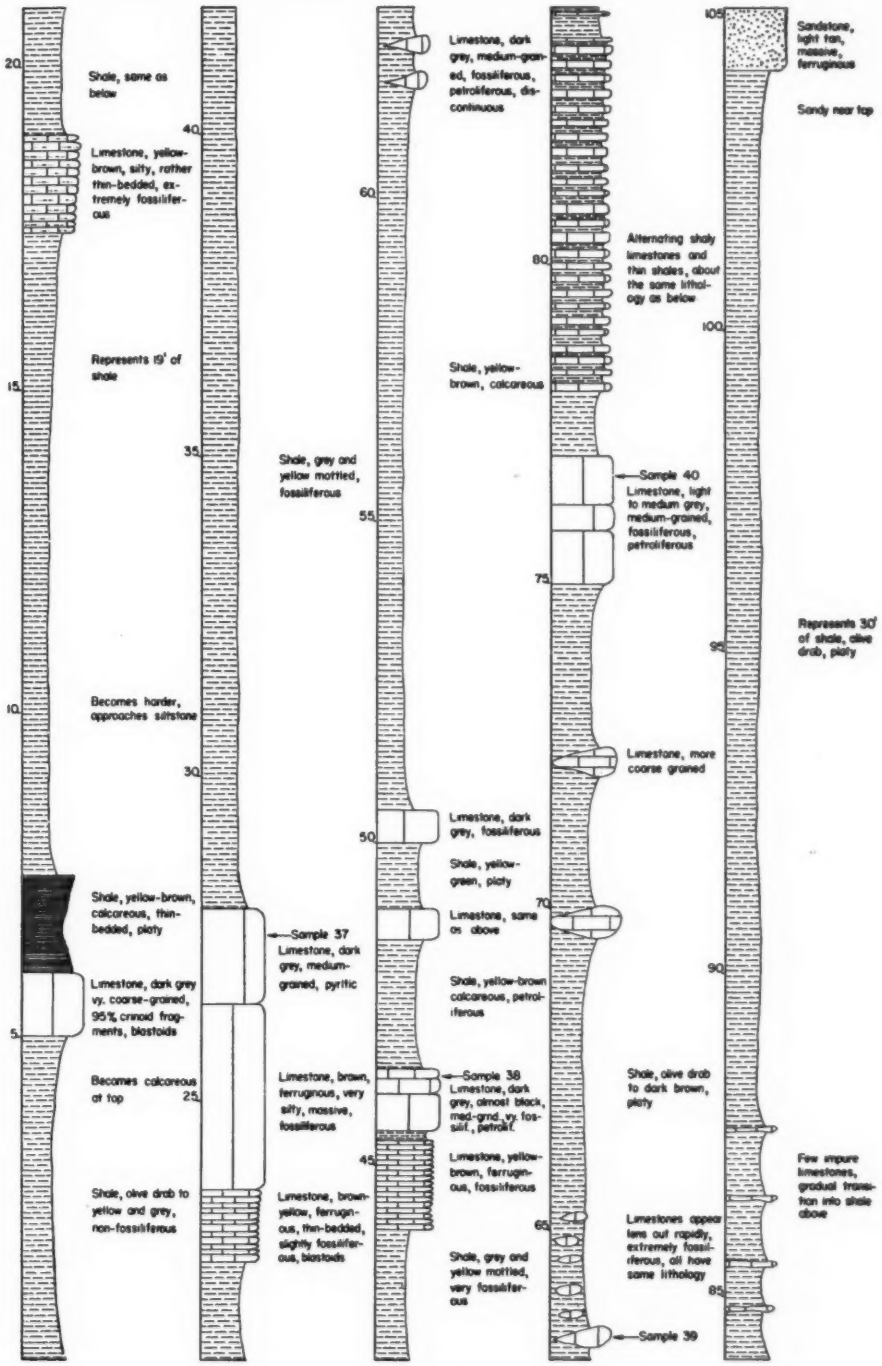

FIG. 4—Golconda formation, no. 2.

which are thickened on their posterior surfaces. *P. pandorae* is characterized by its low angular distortion, regular chambers, weak secondary deposits, and septa which

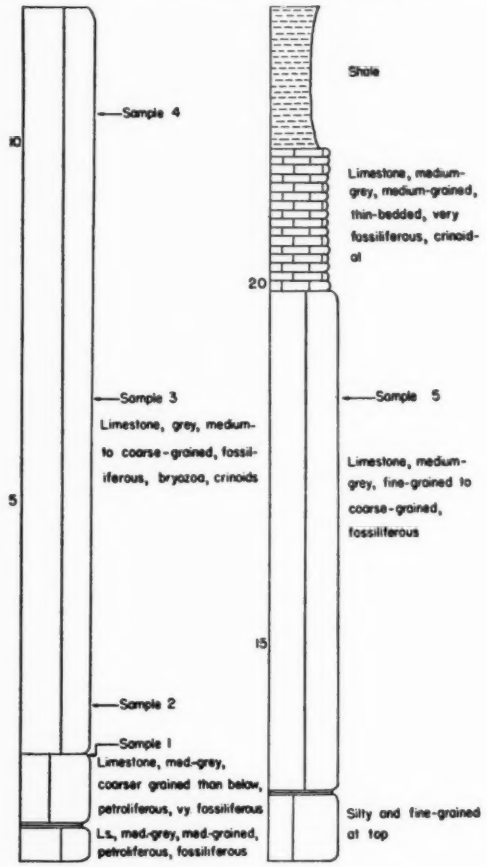

FIG. 5—Glen Dean limestone, type.

curve downward from the spirotheca at nearly right angles.

There is a planispiral form in the Menard limestone which is smaller than the plectogyroids. It has moderately thin walls and has the initial development of chomata.

Clore forms.—The plectogyroids in the Clore limestone are large and are slightly swollen between the sutures. Two species are recognized, *Plectogyra excellens* Zeller, n. sp., and *P. pandorae*, present also in the overlying Menard limestone. *P. excellens* is characterized by its large size, continuous, massive secondary deposits with a well-developed hook, and rather thin walls.

Planispiral forms are present in the Clore limestone and most of them are very large in size. Most are involute with the exception of the last volution. One form is evolute throughout most of the test, but the first two or three volutions are involute. This

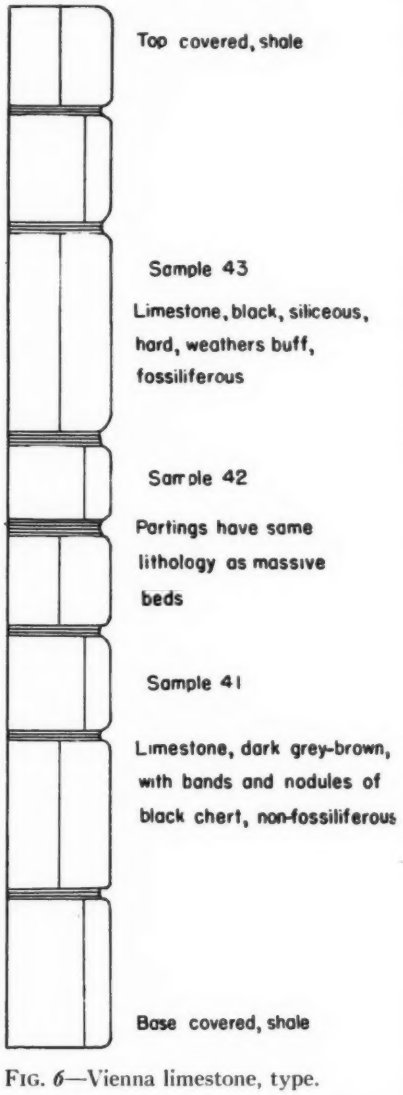
Top covered, shale
Sample 43
Limestone, black, siliceous, hard, weathers buff, fossiliferous
Sample 42
Partings have same lithology as massive beds
Sample 41
Limestone, dark grey-brown, with bands and nodules of black chert, non-fossiliferous
Base covered, shale

FIG. 6—Vienna limestone, type.

form is the one which most closely approaches *Millerella* in size and other general characteristics. Unfortunately, comparatively few sagittal sections were obtained and septal counts were not determined for this larger form. Chomata are present but

are erratic in their development. The proloculus is medium to large in size and the walls are not thin. The tunnel is low. The septa are somewhat anteriorly directed.

Kinkaid forms.—Plectogyroids in the Kinkaid limestone are moderately large. They possess well-developed secondary deposits in the form of hooks, nodes, and filling on the floor of the chambers. The proloculus is large, as in earlier forms. The septa are strongly anteriorly directed. Two species are found in the Kinkaid limestone, *Plectogyra phrissa* Zeller, n. sp., and *P. versabilis*. The latter was discussed above from the Glen Dean limestone. *P. phrissa* is distinguished by its large chambers which are strongly inflated between the sutures, fairly well-developed secondary deposits with hooks and nodes, and thin connecting secondary deposits. The septa are moderately long and arcuate.

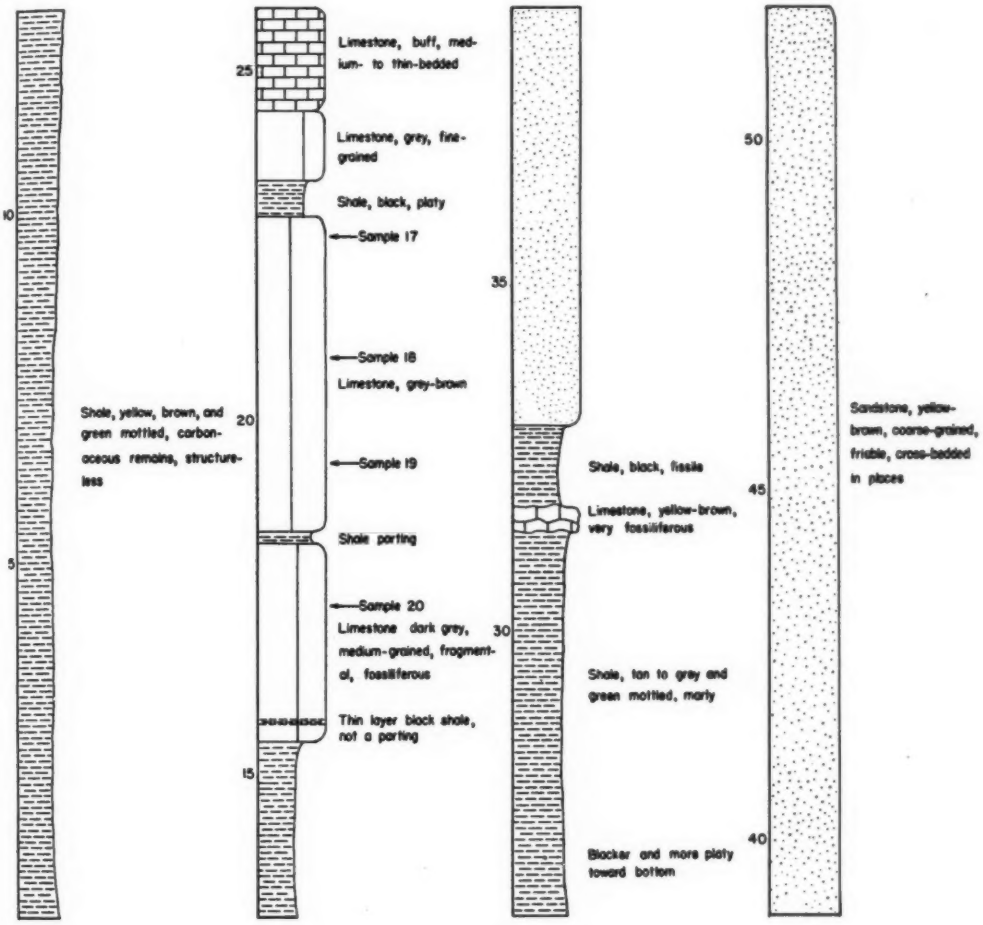

FIG. 7—Menard limestone, type.

The planispiral forms in the Kinkaid limestone are markedly different from the planispiral forms in the Clore limestone. Nearly all are completely involute. Most are non-umbilicate. The proloculus is large. The periphery is broadly rounded and the mid-portion is inflated, giving axial sections a lenticular appearance. Secondary deposits are very thin, chomata are weak. The septal count per volution more closely approaches that of the Pennsylvanian genus *Millerella*.

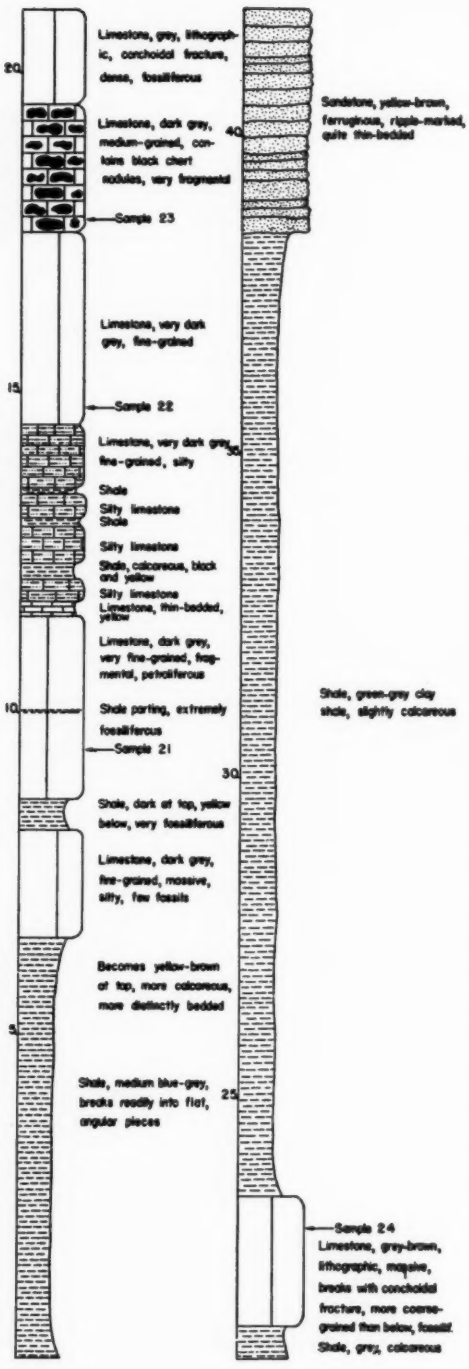
Limestone, gray, lithographic, conchoidal fracture, dense, fossiliferous
Limestone, dark gray, medium-grained, contains black chert nodules, very fragmental
Sample 23
Limestone, very dark gray, fine-grained
Sample 22
Limestone, very dark gray, fine-grained, silty
Shale
Silty limestone
Shale
Silty limestone
Shale, calcareous, black and yellow
Silty limestone
Limestone, thin-bedded, yellow
Limestone, dark gray, very fine-grained, fragmental, petroliferous
Shale parting, extremely fossiliferous
Sample 21
Shale, dark at top, yellow below, very fossiliferous
Limestone, dark gray, fine-grained, massive, silty, few fossils
Becomes yellow-brown at top, more calcareous, more distinctly bedded
Shale, medium blue-gray, breaks readily into flat, angular pieces
Sandstone, yellow-brown, ferruginous, ripple-marked, quite thin-bedded
Shale, green-gray clay shale, slightly calcareous
Sample 24
Limestone, grey-brown, lithographic, massive, breaks with conchoidal fracture, more coarse-grained than below, fossil
Shale, grey, calcareous
20
15
10
5
40
30
25

FIG. 8—Clore limestone, no. 2.

The wall thickness also compares favorably with that of *Millerella*. There is no evidence of an aperture.

SYSTEMATIC DESCRIPTIONS

Order FORAMINIFERA d'Orbigny, 1826
Family FUSULINIDAE Möller, 1878
Genus MILLERELLA Thompson, 1942

Millerella THOMPSON, 1942, Am. Jour. Sci., vol. 240, no. 6, p. 404; 1944, Kansas Geol. Survey, Bull. 52, p. 419; 1945, Kansas Geol. Survey, Bull. 60, p. 40.

The original diagnosis and description of the genus *Millerella* is as follows: (Thompson, 1942, pp. 404–405)

Shell minute, discoidal, with short axis of coiling and narrowly rounded to sub-angular periphery; planispiral throughout growth. The inner three to four volutions are involute but the outer one or two volutions of mature specimens become partially evolute and they only reach approximately one-half the distance to the poles of the preceding volution. Polar regions of mature specimens are depressed (umbilicate). Mature specimens consist of four to seven volutions and measure about 0.3 to 0.6 mm. in width and less than 0.3 mm. in axial length. Spirotheca very thin, consisting of a thin middle layer (tectum and diaphanotheca?) and very thin upper and lower layers which may be tectoria. However, the middle layer is the only layer which can be recognized in all specimens. The rate of expansion of the shell is essentially uniform. Septa are very thin and numerous, and they show a prominent curving in well oriented sagittal sections. Proloculum minute; tunnel low and narrow and bounded by low, narrow chomata.

Representatives of *Millerella* can be distinguished from those of most of the other of the fusulinid genera by their short axis of coiling, narrowly rounded to sub-angular periphery, evolute outer volutions, and prominently curving septa. Representatives of *Millerella* differ from those of the genus *Ozawainella* Thompson by their evolute outer volutions, less sharply angular periphery, much more poorly developed chomata, and smaller size of mature specimens. The genotype of *Nummulostegina* Schubert, *N. velibitana* Schubert, is very poorly known but Schubert's illustrations of external views show completely involute specimens and they also indicate that representatives of the genus *Nummulostegina* are more highly inflated than are those of *Millerella*.

MILLERELLA TORTULA D. Zeller, n.sp.
Plate 26, figs. 7–10, 12–21, 23–26

Shell discoidal, small, umbilicate; periphery broadly rounded; proloculus very small; juvenarium plectogyroid; coiling essentially planispiral; coiling elongate about juve-

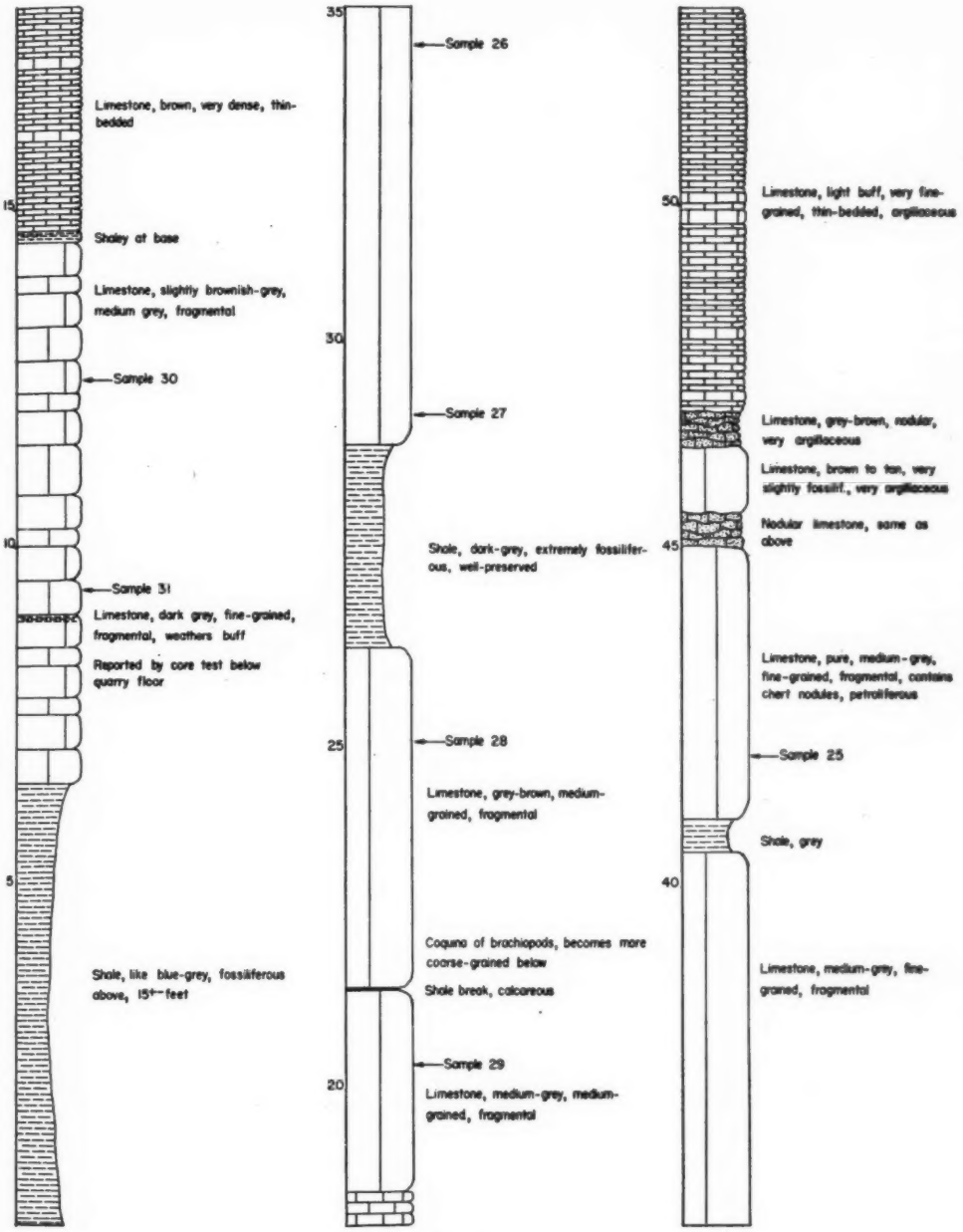

FIG. 9—Kinkaid limestone, type.

narium, resulting in slightly elliptical outline of sagittal section; last volution partly evolute, forming slightly umbilicate shell, the degree of concavity of the umbilicus being unequal on opposite sides; walls thick; septa slightly anteriorly directed; secondary deposits consist of low, erratic chomata; number of chambers less than in Pennsylvanian forms of the genus. Other differences are shown by the table of measurements which were compiled for direct comparison (table I).

TABLE I (mm.)

Specimen	Septal Count					Prol. diam.	Length	Width	Ratio	Height of vol.					Wall Thickness*
	1	2	3	4	5					1	2	3	4	5	
1	—	7	10	14	—	.034	—	—	—	.022	.032	.061	—	—	.0097
2	—	—	—	—	—	.027	.079	.29	1:.37	.015	.024	.046	.067	—	.012
3	5	10	14	—	—	.027	—	.25	—	.024	.031	.045	—	—	.010
4	—	—	—	—	—	.025	.081	.33	1:.41	.018	.030	.052	.072	—	.012
5	6	8	10	—	—	.031	—	.27	—	.021	.025	.036	.053	—	.0073
6	7	12	13	—	—	.030	—	.33	—	.028	.032	.046	—	—	.0089
7	—	—	—	—	—	.025	.102	.34	1:.33	.023	.034	.048	.061	—	—
8	—	—	—	—	—	.028	.085	.29	1:.34	.017	.023	.031	.057	—	.012
9	—	—	—	—	—	.027	.089	.27	1:.30	.029	.038	.061	—	—	.0089
10	—	7	10	14	—	.026	—	.29	—	.016	.023	.027	.042	.068	.0121
11	—	—	—	—	—	.031	.099	.36	1:.36	.017	.028	.046	.062	—	.0137
12	—	—	—	—	—	.024	.080	.26	1:.33	.018	.025	.036	.041	—	.0080
13	—	7	10	13	—	.025	—	.22	—	.024	.036	.045	—	—	.0065
14	—	—	—	—	—	.023	.094	.30	1:.32	.014	.017	.039	.036	.066	.0130
15	7	9	12	15	—	.027	—	.21	—	.011	.021	.027	.051	—	.0080
16	—	—	—	—	—	.023	.079	.30	1:.38	.012	.021	.038	.066	—	.008

Explanation of Table I.—Specimen 1 is fig. 21, a sagittal section; specimen 2 is fig. 22, an axial section; specimen 3 is fig. 9, a sagittal section; specimen 4 is fig. 25, an axial section; specimen 5 is fig. 16, a sagittal section; specimen 6 is fig. 23, a sagittal section; specimen 7 is fig. 24, an axial section; specimen 8 is fig. 18, an axial section; specimen 9 is fig. 13, an axial section; specimen 10 is fig. 26, a sagittal section; specimen 11 is fig. 10, a sagittal section; specimen 12 is fig. 14, an axial section; specimen 13 is fig. 8, a sagittal section; specimen 14 is fig. 19, an axial section; specimen 15 is fig. 7, a sagittal section; specimen 16 is fig. 15, an axial section. All specimens in Table I are illustrated on Plate 26.
* Wall thickness was measured in the last volution.

Millerella tortula differs from *M. designata* in its smaller size and smaller number of volutions.

Glen Dean limestone (type section), samples 1, 4.

MILLERELLA DESIGNATA D. Zeller, n. sp.
Plate 26, figs. 1–6

Shell discoidal; larger than other Chesteran species; umbilicate; periphery broadly rounded; proloculus small; juvenarium slightly plectogyroid, making coiling slightly elongate in one direction; entire last volution evolute; septa anteriorly directed; secondary deposits thin, irregular; number of chambers less than in Pennsylvanian forms of the genus. Data on shell measurements and septal counts are shown in table II.

Clore limestone (type section), samples 1, 2.

MILLERELLA COOPERI D. Zeller, n. sp.
Plate 27, figs. 1–11

Shell lenticular, completely involute; periphery very broadly rounded; proloculus large; juvenarium very slightly plectogyroid but does not cause noticeable elongation of shell; walls thin; secondary deposits sparse and irregular, but chomata are present; number of chambers approaches the number in Pennsylvanian forms of the genus; septa less strongly directed anteriorly than in forms below, some approach right angles as they curve down from the spirotheca. This species is named in honor of Chalmer L. Cooper. Data on shell measurements and septal counts are shown in Table III.

Millerella cooperi differs from other Chesteran species in its form ratio, greater number of chambers per volution, larger proloculus, and more nearly planispiral manner of coiling.

TABLE II (mm.)

Specimen	Septal Count					Prol. diam.	Length	Width	Ratio	Height of vol.					Wall Thickness*
	1	2	3	4	5					1	2	3	4	5	
1	—	—	—	—	—	.026	.081	.46	1:.57	.015	.026	.040	.048	.097	.015
2	7	9	10	11	—	.030	—	.28	—	.010	.027	.038	.060	—	.012
3	—	—	—	—	—	.026	.041	.19	1:.46	.015	.018	.027	.040	—	.005
4	—	—	—	—	—	.027	.081	.36	1:.44	.031	.033	.051	.053	—	.011
5	—	—	—	—	—	.024	.081	.49	1:.42	.031	.041	.068	.081	—	.011
6	—	—	—	—	—	.031	.081	.49	1:.60	.019	.027	.035	.077	.097	.015

Explanation of Table II.—Specimen 1 is fig. 2, an axial section; specimen 2 is fig. 5, a sagittal section; specimen 3 is fig. 6, an axial section; specimen 4 is fig. 3, an axial section; specimen 5 is fig. 1, an axial section; specimen 6 is fig. 4, an axial section. All specimens in Table II are illustrated on Plate 26.
* Wall thickness was measured in the last volution.

Kinkaid limestone (type section), samples 26, 27, 30, 31.

Family ENDOTHYRIDAE Rhumbler, 1895
Subfamily ENDOTHYRINAE Brady, 1884
Genus PLECTOGYRA E. J. Zeller, 1950

Plectogyra E. J. ZELLER, 1950, Univ. of Kansas Paleo. Contr., Protozoa, Art. 4, p. 3–4.

The original diagnosis and description of the genus *Plectogyra* is as follows (E. J. Zeller, 1950, p. 3):

The new genus is founded on *Plectogyra plectogyra*, new species, from the St. Louis limestone, Meramecian (Mississippian), at St. Louis, Mo., as the genotype.

The shell is discoidal and probably umbilicate on one side only. It is involute, having a broadly rounded keel, chambers swollen between the sutures, and the apertural face asymmetrical during most stages of growth. The aperture, which is low and slitlike, is situated at the center of the base of the apertural face and reflects its asymmetry. A tunnel or low passage extends back through the entire coil to the proloculus and is secondarily enlarged by resorption, the height of the tunnel commonly being a little greater than the height of the aperture.

The coiling is particularly distinctive in being logarithmic in character, but the spiral is twisted along an axis so that a three-dimensional spiral is produced. The amount of twisting which takes place during generation of the spiral is called the degree of angular or rotational distortion. The total rotational angle, defined as the sum of all of the angles between each of the half-volution tangent planes, observed in the genotype species, is found to be intermediate between that of strongly distorted forms in Chesterian beds and that of less distorted forms of Kinderhookian rocks. This type of spiral has been defined (Scott, Zeller, and Zeller, 1947, p. 558) as endothyroid, but now it seems desirable to call it a plectogyroid spiral.

The wall of *Plectogyra* is calcareous. There are two distinct layers, a less distinct third layer, and well developed secondary deposits. The outer wall appears as a thin, dark line in thin sections, resembling the tectum of fusulinids. This outer wall undoubtedly contains more organic material than do any of the other layers of the wall. The major portion of the shell wall is made up of material which probably corresponds to the tectorium of fusulinids.

The proloculus of *Plectogyra plectogyra* is about 80 microns in diameter, but it is not perfectly shown by the holotype. The thickness of the wall in the last volution averages about 60 microns. There are nine septa in the last volution, and it is the only whorl in which all of the septa are visible. The maximum diameter of the shell is about 540 microns. The secondary deposits are well developed and appear as rounded nodes of amorphous calcite on the floor of the chambers directly behind the septal ends. The secondary deposits are invariably best developed in the last-formed chamber, directly behind the aperture, and they are partly resorbed in the older chambers. The deposit in the terminal chamber probably forms a ridge behind the aperture producing a vestibule.

TABLE III (mm.)

Specimen	Septal Count					Prol. diam.	Length	Width	Ratio	Height of vol.					Wall Thickness*
	1	2	3	4	5					1	2	3	4	5	
1	6	10	11	10	—	.025	—	.34	—	.023	.027	.047	.093	—	.0097
2	6	10	13	—	—	.026	—	.24	—	.019	.027	.040	—	—	.0089
3	7	9	10	12	—	.029	—	.44	—	.031	.036	.070	.097	—	.0097
4	—	—	—	—	—	.028	.097	.23	1:.24	.019	.024	.033	.042	—	.0081
5	—	—	—	—	—	.025	.145	.26	1:.18	.015	.023	.040	.054	—	.0065
6	—	—	—	—	—	.031	.142	.25	1.:18	.014	.020	.037	.047	—	.0121
7	—	—	—	—	—	.034	.145	.32	1:.22	.022	.028	.037	.075	—	.0104
8	6	10	12	—	—	.029	—	.21	—	.016	.023	.040	—	—	.0081
9	—	—	—	—	—	.022	.130	.30	1:.23	.023	.025	.027	.041	.063	—
10	—	—	—	—	—	.029	.150	.31	1:.21	.023	.026	.053	.058	—	.0073

Explanation of Table III.—Specimen 1 is fig. 5, a sagittal section; specimen 2 is fig. 11, a sagittal section; specimen 3 is fig. 1, a sagittal section; specimen 4 is fig. 9, an axial section; specimen 5 is fig. 3, an axial section; specimen 6 is fig. 4, an axial section; specimen 7 is fig. 10, an axial section; specimen 8 is fig. 7, a sagittal section; specimen 9 is fig. 8, an axial section; specimen 10 is fig. 6, an axial section. All specimens in Table III are illustrated on Plate 27.
* Wall thickness was measured in the last volution.

PLECTOGYRA TANTALA D. Zeller, n. sp.
Plate 27, figs. 14, 16, 17

Shell discoidal, umbilicate on one side only, with broadly rounded periphery; chambers swollen between sutures; proloculus small; secondary deposits not highly developed, single low hook present in final chamber directly behind aperture; bases of hooks preserved in some chambers; aperture low; total angular distortion comparatively small; walls finely granular, often poorly

preserved and indistinct; a few specimens show well-developed tectum; septa show slight anterior inclination and are fairly long.

Plectogyra tantala differs from *P. versabilis* in its less extensive secondary deposits and in the regularity of its chambers. *P. tantala* differs from *P. kentuckyensis* in its less extensive secondary deposits and possession of a hook.

Paint Creek limestone, Section no. 2, sample 11.

PLECTOGYRA KENTUCKYENSIS D. Zeller, n. sp.
Plate 28, figs. 16, 17

Shell discoidal, umbilicate on one side only; chambers large, not strongly swollen between sutures; proloculus of moderate size; secondary deposits well-developed, extending far back into the earlier volutions, consisting of low nodes without sharp hooks; deposits in last chamber do not show hook-like form; aperture moderately high; total angular distortion fairly large; walls finely granular, often not well preserved; septa regularly curved and long.

Plectogyra kentuckyensis differs from *P. versabilis* in its more regular addition of chambers and from *P. pandorae* in its possession of nodes on the heavy secondary deposits.

Glen Dean limestone (type section), sample 1.

PLECTOGYRA VERSABILIS D. Zeller, n. sp.
Plate 28, figs. 2, 18

Shell discoidal, umbilicate on one side only, with highly irregular outer surface; chambers not uniformly inflated between the sutures; proloculus small; secondary deposits very well-developed, massive hook present in final chamber and thick secondary deposits with low nodes in each chamber extend backward on the spirotheca throughout the inner portions of the shell; total angular distortion fairly small; walls appear to be finely granular; tectum frequently visible; walls irregular in thickness, appearing to be very thin in last two or three chambers; septa irregular, showing varying degrees of inclination toward the anterior, most strongly inclined toward the anterior.

Plectogyra versabilis differs from *P. tantala* in having extensive secondary deposits and in the irregularity of its chambers. It differs from *P. kentuckyensis* principally in the irregularity of its chambers and in the lesser degree of angular distortion.

Glen Dean limestone (type section), sample 1. Kincaid limestone (type), sample 31.

PLECTOGYRA PANDORAE D. Zeller, n. sp.
Plate 28, figs. 7, 10, 13, 14

Shell discoidal, broadly rounded periphery; umbilicate on one side only; chambers regular; only slightly swollen between the sutures; proloculus moderately small; sec-

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EXPLANATION OF CHART I

Small letters beside the inked specimens indicate the formation from which the specimens came.

FIGS. R_1, R_2—*Plectogyra* sp.
PC_1—*Plectogyra tantala* D. Zeller, n. sp. Drawing of the holotype.
PC_2—*Plectogyra tantala* D. Zeller, n. sp.
PC_3—*Millerella?* sp.
GD_1—*Plectogyra versabilis* D. Zeller, n. sp. Drawing of the holotype.
GD_2—*Plectogyra kentuckyensis* D. Zeller, n. sp. Drawing of the holotype.
GD_3, GD_4, GD_6, GD_7, GD_8—*Millerella tortula* D. Zeller, n. sp.
GD_5—*Millerella tortula* D. Zeller, n. sp. Drawing of the holotype.
V_1, V_2—*Plectogyra* sp.
M_1—*Plectogyra maxima* D. Zeller, n. sp. Drawing of the holotype.
M_2—*Millerella* sp.
C_1—*Plectogyra excellens* D. Zeller, n. sp. Drawing of the holotype.
C_2, C_3—*Plectogyra* sp.
C_4, C_5—*Millerella designata* D. Zeller, n. sp. Drawings of paratypes.
C_6—*Millerella designata* D. Zeller, n. sp. Drawing of the holotype.
K_1—*Plectogyra phrissa* D. Zeller, n. sp. Drawing of the holotype.
K_2—*Plectogyra versabilis* D. Zeller, n. sp. Drawing of a paratype.
K_3, K_4, K_5, K_7—*Millerella cooperi* D. Zeller, n. sp.
K_6—*Millerella cooperi* D. Zeller, n. sp. Drawing of the holotype.

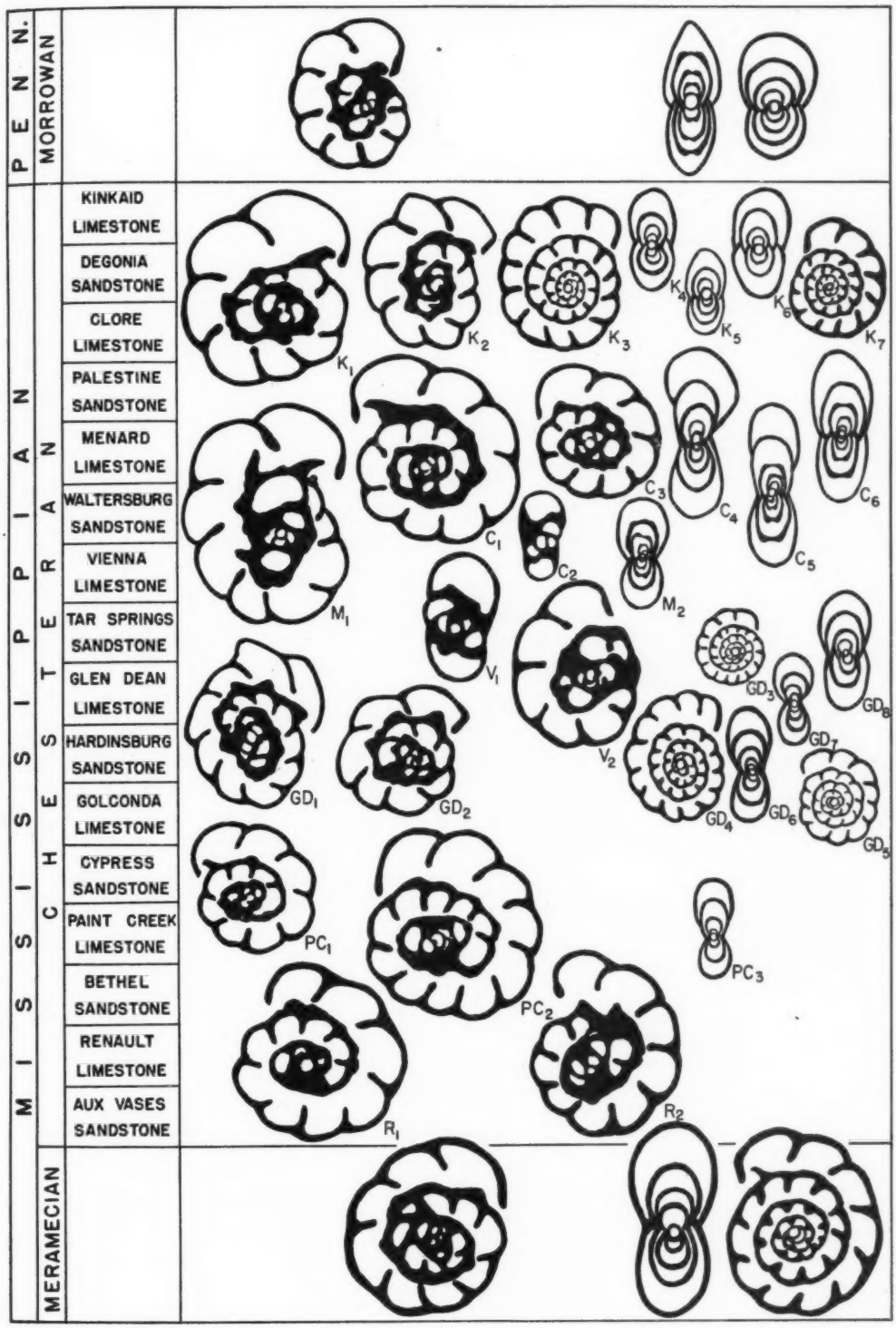
PENN.
MORROWAN
MISSISSIPPIAN
CHESTERAN
MERAMECIAN
KINKAID LIMESTONE
DEGONIA SANDSTONE
CLORE LIMESTONE
PALESTINE SANDSTONE
MENARD LIMESTONE
WALTERSBURG SANDSTONE
VIENNA LIMESTONE
TAR SPRINGS SANDSTONE
GLEN DEAN LIMESTONE
HARDINSBURG SANDSTONE
GOLCONDA LIMESTONE
CYPRESS SANDSTONE
PAINT CREEK LIMESTONE
BETHEL SANDSTONE
RENAULT LIMESTONE
AUX VASES SANDSTONE
K1
K2
K3
K4
K5
K6
K7
C1
C2
C3
C4
C5
C6
M1
M2
V1
V2
GD1
GD2
GD3
GD4
GD5
GD6
GD7
GD8
PC1
PC2
PC3
R1
R2

CHART I

ondary deposits not highly developed, consisting of a single low node in the last one or two chambers; total angular distortion moderate; aperture low; septa curve sharply downward at nearly right angles, showing little anterior inclination.

Plectogyra pandorae differs from *P. excellens* in its less extensive secondary deposits and in its thicker walls and less swollen chambers.

Menard limestone (type section), sample 20.

Clore limestone (type section), sample 1.

PLECTOGYRA MAXIMA D. Zeller, n. sp.
Plate 28, fig. 15

Shell extremely large, elongate; umbilicate on one side only; chambers large, strongly arched; proloculus relatively small in relation to size of test; secondary deposits very strongly developed, but connective layers usually incomplete in last-formed part of shell; deposits consist of large forward-curving hooks directly behind each septum; resorption in the earlier chambers reduces the size of the hooks; septa show slight thickening on posterior surface; total angular distortion very large; walls finely granular and thin in relation to size of shell.

Plectogyra maxima differs from other new species in its extreme size, in the exceptional development of hooks, and in its high angular distortion.

Menard limestone (type section), sample 19.

PLECTOGYRA EXCELLENS D. Zeller, n. sp.
Plate 28, figs. 8, 9

Shell discoidal, large in size, with broadly rounded periphery; umbilicate on one side only; chambers large, inflated; proloculus small; secondary deposits very well-developed, massive, continuous; well-developed hook present in the last chamber; septa short, directed slightly anteriorly; tectum well shown; walls rather thin, very finely granular; aperture high.

Plectogyra excellens differs from *P. pandorae* in its more extensive, better developed secondary deposits and in its thinner walls and more inflated chambers. *P. excellens* differs from *P. versabilis* in its larger size and more regularly formed chambers. *P. excellens* differs from *P. phrissa* in its more massive secondary deposits and less strongly distorted coiling.

Clore limestone (type section), samples 1, 2.

PLECTOGYRA PHRISSA D. Zeller, n. sp.
Plate 28, figs. 1, 4, 6

Shell discoidal; umbilicate on one side only; chambers very large and strongly inflated; proloculus large; secondary deposits fairly well-developed, a hook being present in the final chamber and nodes in the preceding chambers; secondary deposits connecting the nodes fairly thin and somewhat irregular; total rotational distortion extremely high; septa moderately long and strongly arcuate with some evidence of light secondary deposits on posterior surfaces; walls rather thin, granular; aperture fairly high.

Plectogyra phrissa differs from *P. excellens* in its less massive secondary deposits and more strongly distorted coiling. *P. phrissa* differs from *P. kentuckyensis* in its lighter connecting deposits, in its possession of a distinct hook in the last chamber, and in its more highly distorted manner of coiling.

Kinkaid limestone (type section), sample 30.

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ECOLOGY AND PALEOECOLOGY OF SOME CALIFORNIA FORAMINIFERA. PART II. FORAMINIFERAL EVIDENCE OF SUBSIDENCE RATES IN THE VENTURA BASIN[1]

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ABSTRACT—Data from the Wheeler Canyon section of the Ventura Basin show evidence of a much greater rate of subsidence than filling in early Pliocene time; perhaps some uplift followed by about equal rates of subsidence and filling during middle Pliocene time; considerable subsidence accompanied by about an equivalent amount of filling in the late Pliocene time; and an initial uplift followed by some subsidence and complete filling of the basin in the early Pleistocene.

INTRODUCTION

THE Ventura Basin is selected as an example of how Recent data may be applied to the interpretation of paleoecology. Natland and Kuenen (1951) have already showed that during the late Cenozoic coarse materials were carried into deep water by turbidity flows, submarine sliding and associated phenomena. Characteristic Foraminifera of the major divisions of Wheeler Canyon were named and the present occurrence of these same species off the coast of California was used as a basis for indicating the depth of water during the accumulation of sediments for the Pliocene and Pleistocene. The data for the Wheeler Canyon section are plotted graphically in figure 3. The depth-temperature ranges are modified slightly in accordance with the findings of the present investigation.

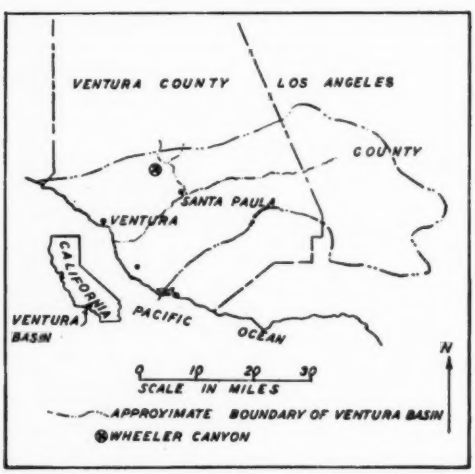

FIG. 1—Ventura Pliocene Basin (after Natland and Kuenen, 1951).

PALEOECOLOGY[2]

Inspection of figure 3 and comparison of these faunal zones with those existing off the coast today (Bandy, 1953, figs. 3, 4) show clearly why the temperature conditions suggested by the faunas are not valid indications of the temperature along the coast throughout the late Cenozoic. Nearly all of the Pliocene assemblages suggest deposition at great depth (bathyal conditions); hence, much colder conditions are suggested than must have prevailed in the very shallow coastal waters. The Pleistocene assemblages, however, are typically those now best developed in the shallower waters of the continental shelf (neritic zone), thereby reflecting more dependably the temperature conditions in the shallow coastal waters at that time. According to Natland and Kuenen (1951), the Pliocene assemblages of the Ventura Basin are represented by living faunas off La Jolla; and it can be added that the same general faunas are found off Point

[1] Contribution No. 103 of the Allan Hancock Foundation, University of Southern California, Los Angeles, California.

[2] The species referred to herein are listed and figured in Part I of this investigation.

Arguello and San Francisco. During early Pleistocene time, the faunas of the Wheeler Canyon section were mostly identical with those now inhabiting the colder waters north of Point Arguello. *Elphidiella hannai* is an important member of the upper part of the lower Pleistocene sediments of the Wheeler Canyon fauna, and this same species is of high frequency occurrence in the middle neritic zone of the San Francisco profile.

Below is a discussion of the bathymetric conditions of the later Cenozoic time as based upon faunal elements mentioned by Natland and Kuenen (1951).

The Oligocene is represented by continental beds and the upper Miocene by marine sediments containing a fauna which includes *Epistominella pacifica*, *Uvigerina peregrina*, and *Bolivina spissa*. More evidence is needed before the exact characteristics of the entire Miocene bathymetric history can be established. The upper Miocene species are abundant and modern representatives are at present indicative of a water depth of about ±2000 feet (Bandy, 1953). During the early Pliocene, *Bulimina rostrata* and *Nonion pompiliodes* became prominent members of the fauna, and now these species occur at depths of about 6000 feet or more off Point Arguello. Natland and Kuenen (1951) indicate that the shallowest occurrence of these species is between 4000 and 5000 feet. In frequency studies preceding this paper *Nonion pompilioides* was found to be abundant below 8000 feet, whereas *Bulimina rostrata* was most abundant between 6000 and 8000 feet (Bandy, 1953, fig. 3 and table I). From a frequency standpoint, the shallowest depth of maximum development for these two species is probably no less than about 5000 or 6000 feet. The middle Pliocene was characterized by the common occurrence of *Bulimina subacuminata*. This species is very similar to *Bulimina striata* var. *mexicana* and the two species were lumped together under the name of the latter in Part I of this investigation. In Recent sediments this assemblage is most characteristic of a depth of about 3000 feet in the absence of the deeper water species. During late Pliocene time occurred a duplication of late Miocene conditions, in part, in that the same three species are abundant and characteristic in sediments deposited during both times, suggesting a water depth of approximately 2000 feet. During the early Pleistocene, the transition through lower neritic and middle neritic assemblages is fairly rapid. The *Cassidulina limbata* fauna appears in the early part of the Pleistocene followed later by the *Elphidiella hannai* assemblage.

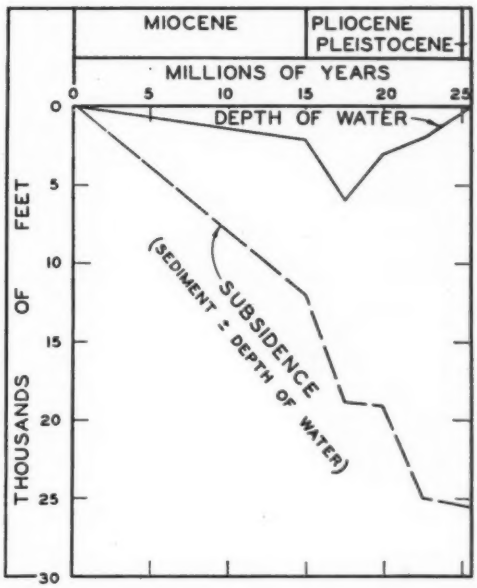

FIG. 2—Tectonic history of the Wheeler Ridge area of the Ventura Basin.

SUBSIDENCE RATES

An attempt is made in figure 2 to demonstrate some of the characteristics of the tectonic history of the Ventura Basin. The data for thicknesses in this example are from Natland and Kuenen (1951). It is assumed that an average figure of 26 million years represents the duration of the time interval from the early Miocene to Recent. About 15 million years of this is ordinarily assigned to the Miocene. A plot was made of the sediment thickness for the Miocene (10,000 feet) plus the depth of water at the close of the Miocene (2,000 feet). This total is 12,000 feet, suggesting that amount of subsidence in about 15 million years. The subsidence was actually much greater inasmuch as the sediment thickness is based on

compacted material; however, this general picture gives workable approximate values.

Early Pliocene.—During early Pliocene time, the depth of water increased fairly rapidly to about 6000 feet—about 4000 feet deeper than in late Miocene time. With the addition of about 2900 feet of sediment

Late Pliocene.—In late Pliocene time, the depth of water decreased to about 2000 feet, 1000 feet shallower than in middle Pliocene time. About 6800 feet of compacted sediment represents the late Pliocene, which means that if the 1000 feet of shallowing is subtracted from this figure, there must have

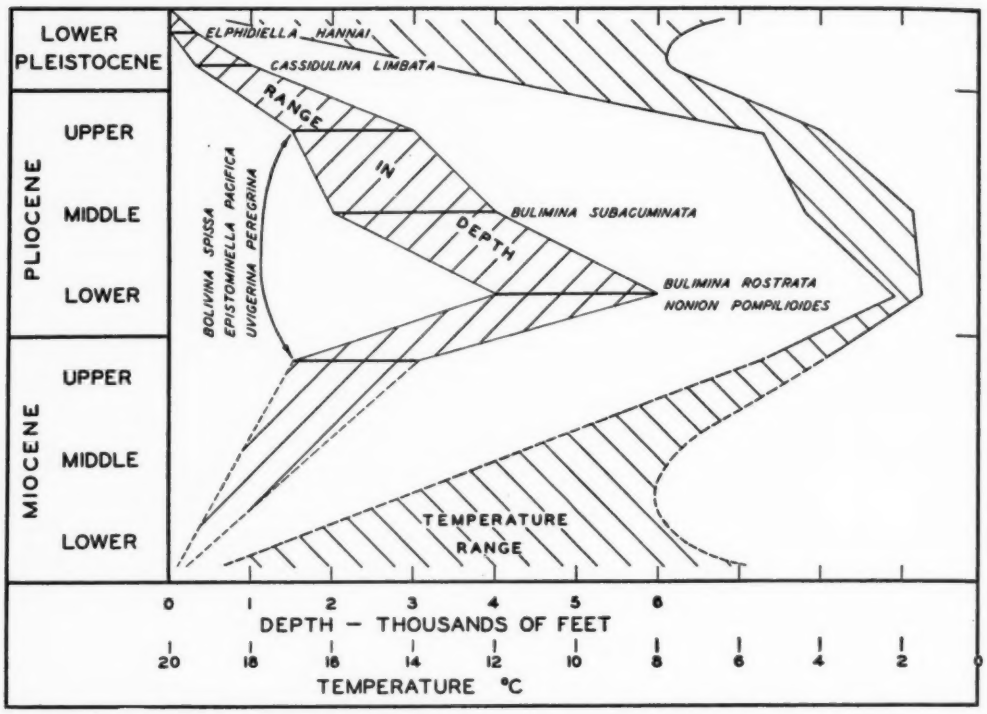

FIG. 3—Depth-temperature variation during the later Cenozoic in the Ventura Basin.

in early Pliocene time, there must have been in excess of 6900 feet of subsidence in the 3 or 4 million years generally assigned to this time interval.

Middle Pliocene.—In middle Pliocene time, the water depth decreased fairly rapidly to about 3000 feet. This decrease is largely explained by the accumulation of about 3200 feet of sediment, compacted thickness. The sediment accumulated throughout the middle Pliocene, hence there must have been uplift in the early part of the middle Pliocene bringing in the shallower faunas, followed by gradual subsidence as the sedimentary blanket accumulated during the 3 or 4 million years representing this time interval.

been in excess of 5800 feet of subsidence in this time interval of about 3 or 4 million years.

Early Pleistocene.—In the early Pleistocene, the water became shallower and finally continental beds were deposited near the middle of the Pleistocene; hence, the water became about 2000 feet shallower than before and at the same time there is now a thickness of about 2400 feet of sedimentary rock representing the early Pleistocene. Early progressive shallowing is suggested by the appearance of middle neritic Foraminifera. In view of this and the fact that compaction must have been continuous in these and in the underlying beds, there may have been an early Pleistocene uplift

followed by slight subsidence, before the general mid-Pleistocene diastrophism of southern California mentioned by Reed (1941, p. 118).

In general, it appears that there has been over 26,000 feet of subsidence represented in the Wheeler Canyon section in some 26 million years. This subsidence has not been continuous and it progressed at varying rates; it was faster in early and late Pliocene times and was punctuated by two intervals of stability or perhaps uplift—the first in middle Pliocene time and the second in the early Pleistocene. The imponderable errors inherent in suggestions of this nature, as based upon paleoecology and stratigraphic thickness, stem from the lack of knowledge of how much change in faunal adaptation has occurred. In view of the use of several species in correlating between Recent and fossil assemblages, perhaps this difficulty is largely overcome. Displaced faunas also offer considerable trouble; however, in frequency studies, the upper limits of abundant occurrence are probably acceptable as the optimum environments of development for the Recent faunas. In fossil assemblages, the error is likely to involve the identification of deep samples as representative of shallow water environments. As pointed out by Natland and Kuenen (1951, p. 83), mixtures of this kind are identifiable if there is a deep-water population of Foraminifera, since they will include mixtures of deep and shallow-water species. In other cases one might expect the coarser laminae representing turbidity flows, etc., to carry the shallow-water species; whereas the thin shales, representing gradual deposition, would carry the deep-water populations.

The Pliocene of the Los Angeles Basin duplicates that of the Ventura Basin in a general way. In early Pliocene time the water was mostly very deep as suggested by the same suites of Foraminifera. The subsequent history follows a similar pattern with about the same species represented in both areas for the middle and late Pliocene. A singular feature of the Pliocene of the northern part of the Los Angeles Basin is the presence of a few thin beds of conglomerate in the section with deep-water Foraminifera between, above and below them. Martin (1952) studied the faunas and concluded that the conglomerates were introduced into deep water. A similar conclusion was made by Natland and Kuenen (1951) concerning some lower Pliocene conglomerates of the Ventura Basin.

CONCLUSIONS

In analyzing the paleoecological conditions in the later Cenozoic history of the Ventura Basin, it is significant that progressively deeper ecologies or biofacies equivalent to those off Point Arguello are generally duplicated in drilling progressively through Pleistocene, upper, middle, and lower Pliocene sediments. The faunas of the upper Miocene suggest water depths comparable to the depths indicated by the upper Pliocene faunas.

Data from Wheeler Canyon in the Ventura Basin show evidence that the rate of subsidence was much greater than the rate of filling in the early Pliocene; that the middle Pliocene was a time of uplift followed by about equal rates of subsidence and filling; that the late Pliocene was a time of considerable subsidence accompanied by about an equivalent amount of filling; and that the early Pleistocene was marked by an initial uplift followed by some subsidence and complete filling of the Basin.

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UPPER CRETACEOUS, TERTIARY, AND RECENT PLANKTONIC FORAMINIFERA FROM MID-PACIFIC FLAT-TOPPED SEAMOUNTS

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ABSTRACT—Foraminifera discussed in this paper were collected by the 1950 Scripps Institution-U. S. Navy Electronics Laboratory Mid-Pacific Expedition. Five flat-topped seamounts ("guyots" of Hess, 1946) were dredged and cored in an area between 600 and 1100 miles west of Hawaii.

The following faunas have been identified:

Basaltic gravel layers in a core at 2050 fathoms near one of the guyots contain an Upper Cretaceous (Campanian-Maestrichtian) fauna including species of *Globotruncana*, striate *Gümbelina*, and *Ventilabrella*, mixed with Tertiary and Recent species.

An upper Paleocene fauna dominated by *Globorotalia velascoensis* occurs in indurated *Globigerina* ooze on top of a second guyot.

Two cores taken on top of another guyot contain a lower-middle Eocene *Globigerina* ooze planktonic assemblage dominated by *Globorotalia aragonensis* and with *Hantkenina mexicana* to within an inch of the top of the core.

Conclusions are that the mixed Cretaceous-Recent fauna and the gravel were transported by turbidity currents to their present location and that the Eocene ooze on top of one guyot is due to non-accumulation of later planktonic sediments.

The Foraminifera date the truncation of one guyot as pre-Upper Cretaceous and two others as pre-Paleocene-Eocene, which generally supports the evidence provided by the "middle" Cretaceous reef coral rudistid fauna dredged from these guyots.

Geographic ranges of many Upper Cretaceous and Tertiary planktonic index species have now been extended into the Middle Pacific. These forms will be useful in dating and solving problems of the sedimentation of deep-sea sediments.

PREFACE

THE MATERIAL on which this paper is based was collected by the 1950 Scripps Institution of Oceanography-U. S. Navy Electronics Laboratory Expedition to Bikini (short name: MidPac). One of the objectives of the expedition was to explore the topography of the Pacific Ocean bottom, especially in areas where there were known flat-topped seamounts ("guyots" of Hess, 1946).

West of Hawaii the MidPac Expedition explored five flat-topped seamounts which are peaks of a great submarine range extending from Necker Island in the Hawaiian Islands to the vicinity of Wake Island (fig. 1). This great submarine range has been named the "Mid-Pacific Mountains." The results of this exploration will be discussed in detail in other reports, but will be summarized here for necessary background.

Echo sounder surveying, dredging, and coring on the guyots revealed that they are the topmost peaks of a basaltic submarine range. These flat-topped seamounts have side slopes approximately 20° near the top. The sides are concave upward with perceptible breaks in slope between the upper side slopes and the flat tops at depths ranging from 720 to 1150 fathoms. The profiles are symmetrical.

Rounded sand grains, pebbles, cobbles, and boulders of olivine basalt were dredged from the tops and below the breaks in slope on the guyots. Sandstone from a basaltic source was dredged on two of the features. Calcium carbonate was present in the form of organic limestone and *Globigerina* ooze.

Dredge hauls near the breaks in slope on two guyots brought up a well-integrated fossil fauna of reef coral, rudistids, stromatoporoids, gastropods, pelecypods, and an echinoid. The age of this assemblage is Cretaceous (Aptian to Cenomanian); the affinities are with the faunas of the Tethyan Province.

The conclusions from the above evidence

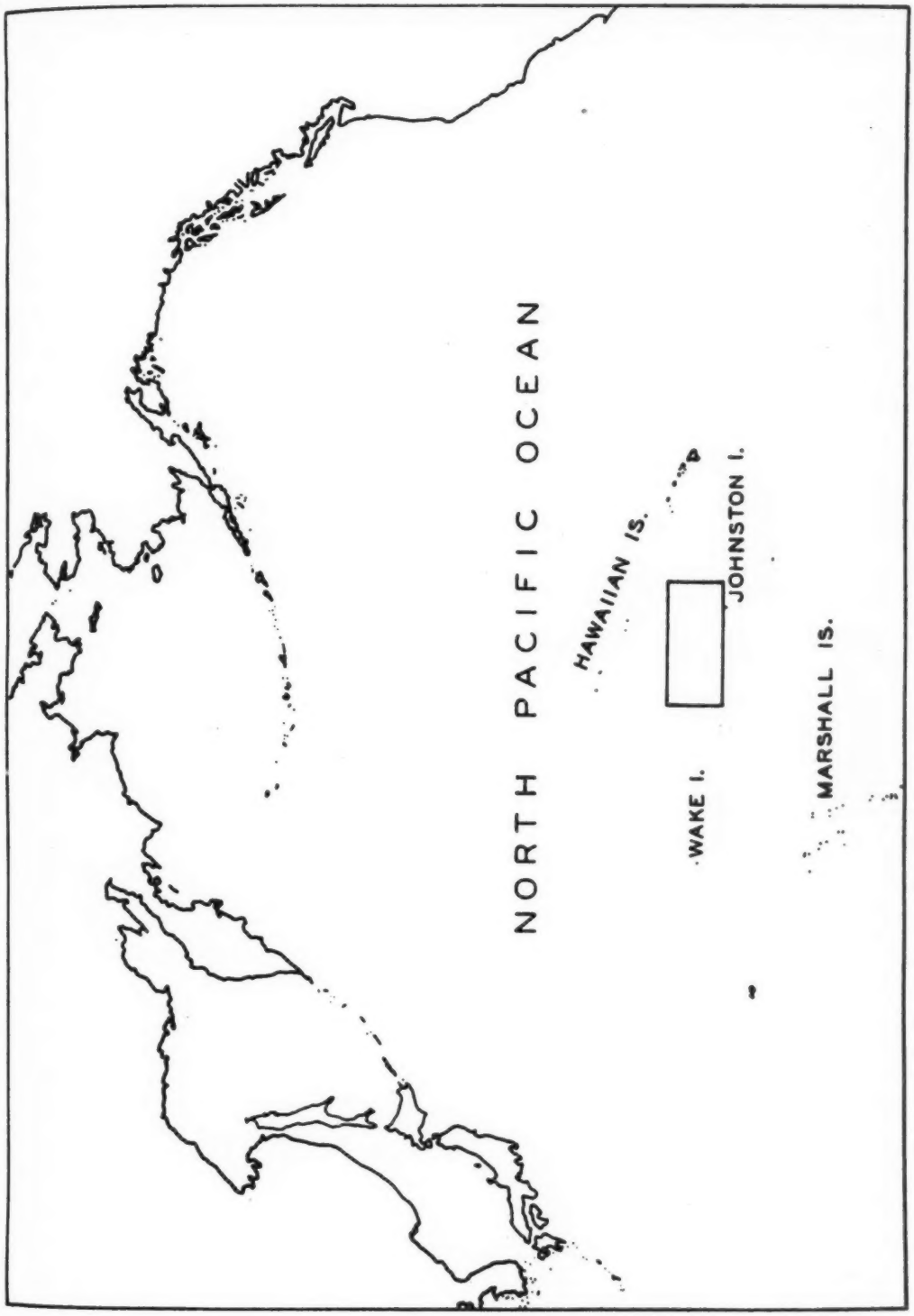

FIG. 1—Index map showing the area (outlined by the rectangle) in which flat-topped seamounts were sampled.

are that during Cretaceous time there was a chain of basaltic islands in the Mid-Pacific where the submarine range now lies; that these islands were wave eroded to flat banks on which a reef coral-rudistid fauna found lodgement. The reef coral was apparently present as banks on and among the erosional debris and the guyots were never fully developed atolls. The truncated volcanic mountains and ridges were submerged during Cretaceous time below the zone of reef coral growth; subsequently the guyots sank to the present depth of around 900 fathoms.

The subject materials of this paper are the fossil planktonic Foraminifera which occur on all five of the sampled guyots.

INTRODUCTION

The planktonic Foraminifera have been largely neglected as primary tools for regional and inter-regional correlation. In recent years, however, several authors have stressed the value of these forms for long-distant correlation (Glaessner, 1937 and 1945; LeRoy, 1948; Stainforth, 1948 and 1950; Bronnimann, 1950, Grimsdale, 1951). A good index fossil should be abundant, geographically widespread, have a short stratigraphic or geologic range, and distinct morphology. The planktonic Foraminifera are widespread and abundant because of large oceanic water masses of comparable ecologic conditions.

Many planktonic Foraminifera have a short range in geologic time and many have distinct morphology. As is well known in micropaleontology, however, these two aspects of planktonic forms are the principal difficulties to the present use of the planktonics in long range correlations. There remains a tremendous amount of work to unravel the synonyms, mistakes in identification, and to refine the "waste-basket" species so that they can be used stratigraphically. Each genus of planktonic Foraminifera should be monographed. When this is accomplished it will be possible to correlate the marine sediments from the Upper Cretaceous to Pliocene on a world-wide basis by using planktonic Foraminifera. In order to establish a sequence of planktonic foraminiferal index fossils, any evidence on their geographic or geologic distribution is desirable.

This paper contributes toward a solution of the problems discussed above by extending the geographic ranges of a number of planktonic index fossils to the Middle Pacific. The establishment of planktonic index fossils for the Pacific Ocean area is of particular interest to the writer and his colleagues for the dating of deep-sea sediments which are normally collected on the various Scripps-Navy Electronics Laboratory expeditions. The ecology of Foraminifera has proved useful in solving problems of sedimentation (an excellent example being Phleger's 1951 paper on displaced foraminiferal faunas). In the area of the flat-topped seamounts all of the assemblages are planktonic, but the ages of the various index fossils have proved extremely useful in studying the sedimentation on and around the guyots.

Data in connection with the sampling stations discussed in this paper are summarized in table 1.

Acknowledgments.—The writer appreciates the helpful suggestions of the following persons who critically read the manuscript: R. S. Dietz, H. W. Menard, F. B. Phleger, Miss F. L. Parker, M. N. Bramlette, H. E. Thalmann, J. J. Graham, Miss Ruth Todd, and Miss Jean F. Peirson.

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TABLE 1.—DATA OF MIDPAC EXPEDITION SAMPLING STATIONS

MP Station	Approximate Positions N. Lat.	Approximate Positions W. Long.	Depth (fathoms)	Sampler	Sample Description	Field Notes and Remarks
25 E-1	19 40	168 32	931	Phleger corer	31″ core *Globigerina* ooze	Just above break in slope on Horizon Guyot; Eocene fauna
25 E-2	19 40	168 32	950	Phleger corer	28″ core *Globigerina* ooze	Just above break in slope on Horizon Guyot; Eocene fauna
26 A-3	19 25	171 00	720–770	Chain-bag dredge	MnO_2 coated fossil *Globigerina* ooze rock; olivine basalt boulders with rounded corners, sandstone pebble, silicified limestone, olivine basalt chips: all covered by MnO_2.	Dredging across break in slope; fossil *Globigerina* ooze rock contains lower-middle Eocene Foraminifera fauna.
27-2 & 2P	19 34	171 54	2050	Piston-type corer with attached Phleger corer (2P)	MP 27-2: 3′ core of red clay with two layers of subrounded to angular, uncoated gravel from basaltic source; 27-2P: Phleger core of *Globigerina* ooze and red clay.	Coring in "basin" near Guyot 20171; both cores contained the same Upper Cretaceous to Recent mixed planktonic fauna.
33 C	17 45	174 16	910–920	Chain-bag dredge	Rounded, white, soft rocks composed of foram tests, and finely divided $CaCO_3$ (indurated *Globigerina* ooze); some had black Mn coating.	Dredging near the top center of Hess Guyot. Foraminifera fauna is probable upper Paleocene.

of the Laboratory which were generously opened to him.

Photographs were retouched by the writer.

Unfortunately, the exact locations of sampling stations cannot be given due to the present policy of the Navy of classifying deep-sea soundings as restricted security information. The locations of all the seamounts concerned, however, are shown on the U. S. Navy Hydrographic Chart No. 0528.

DESCRIPTION AND DISCUSSION OF THE FAUNAS

Present-day fauna.—The present-day fauna in the area investigated (fig. 1) is the tropical and semi-tropical planktonic assemblage of the Pacific previously noted by several authors (Brady, 1884; Cushman, 1910–1916, 1921, 1925; and others).

The following species have been noted in the present-day assemblages which are assumed to be without contamination; these species are the ones referred to as "the present-day tropical Pacific planktonic assemblage."

A count of 300 specimens was made in one sample from Cape Johnson Guyot and the percentage of occurrence of each species is indicated opposite the species name.

Species	Percentage of Occurrence
Globigerina bulloides d'Orbigny	3
G. digitata Brady	−1
G. eggeri Rhumbler	1
G. hexagona Natland	2
G. inflata d'Orbigny	−1
G. quinqueloba Natland	−1
G. subcretacea Lomnicki	1
G. cf. *G. venezuelana* Hedberg	−1
Globigerinita glutinata (Egger)	5
Globigerinoides conglobata (Brady)	12
G. rubra (d'Orbigny)	33
G. sacculifera (Brady)	16
Globorotalia hirsuta (d'Orbigny)	−1
G. menardii (d'Orbginy)	3
G. punctulata (d'Orbigny)	−1
G. scitula (Brady)	1
G. tumida (Brady)	3
G. truncatulinoides (d'Orbigny)	4
Globigerinella aequilateralis (Brady)	5
Candeina nitida d'Orbigny	2
Orbulina universa d'Orbigny	4
Pulleniatina obliquiloculata (Parker and Jones)	3
Sphaeroidinella dehiscens (Parker and Jones)	−1

Cores at MP 27.—Three cores were taken

at MP 27 (MidPac Expedition Station No. 27) at 19°34′N. Lat. and 171°54′W. Long. at a depth of 2050 fathoms. This station was in a basin or deep valley which is a re-entrant into the south side of the main ridge of the Mid-Pacific Mountains and was about 15 nautical miles from the nearest known guyot. No soundings were available on three sides of MP 27 and consequently the topography surrounding the area is largely unknown.

A piston corer used at this station passed through at least two layers of gravel (fig. 2); the lower bed, at a depth of about 26 inches below the surface was graded with large pebbles of basalt at the bottom of the bed. The total length of this core was about three feet. A Phleger Bottom Sampler, or small corer (Phleger, 1951) was attached to the trip arm of the piston corer and took a 34½ inch core.

An examination of the sand and gravel revealed that it was composed of rounded to subangular sand grains, pebbles, and cobbles of basalt. The Foraminifera of this gravel layer are a mixture of Upper Cretaceous to Recent species. This mixed assemblage occurs with little variation throughout both cores. The Phleger Bottom Sampler takes a relatively undisturbed sample of the surface of the sea floor and the upper part of this core was examined carefully. The upper one inch (the present-day sea bottom) was a white, unconsolidated *Globigerina* ooze which contained the Upper Cretaceous to Recent forms mentioned above. A count of 300 specimens revealed that about 55% were fossil. About 25% of the total specimens counted belong to the genus *Globotruncana* and about 11% to the genus *Gümbelina*. The Upper Cretaceous specimens are as well preserved as the apparently Recent material. This mixed fauna includes many of the well known planktonic index fossils of the Paleocene, Eocene, and later epochs.

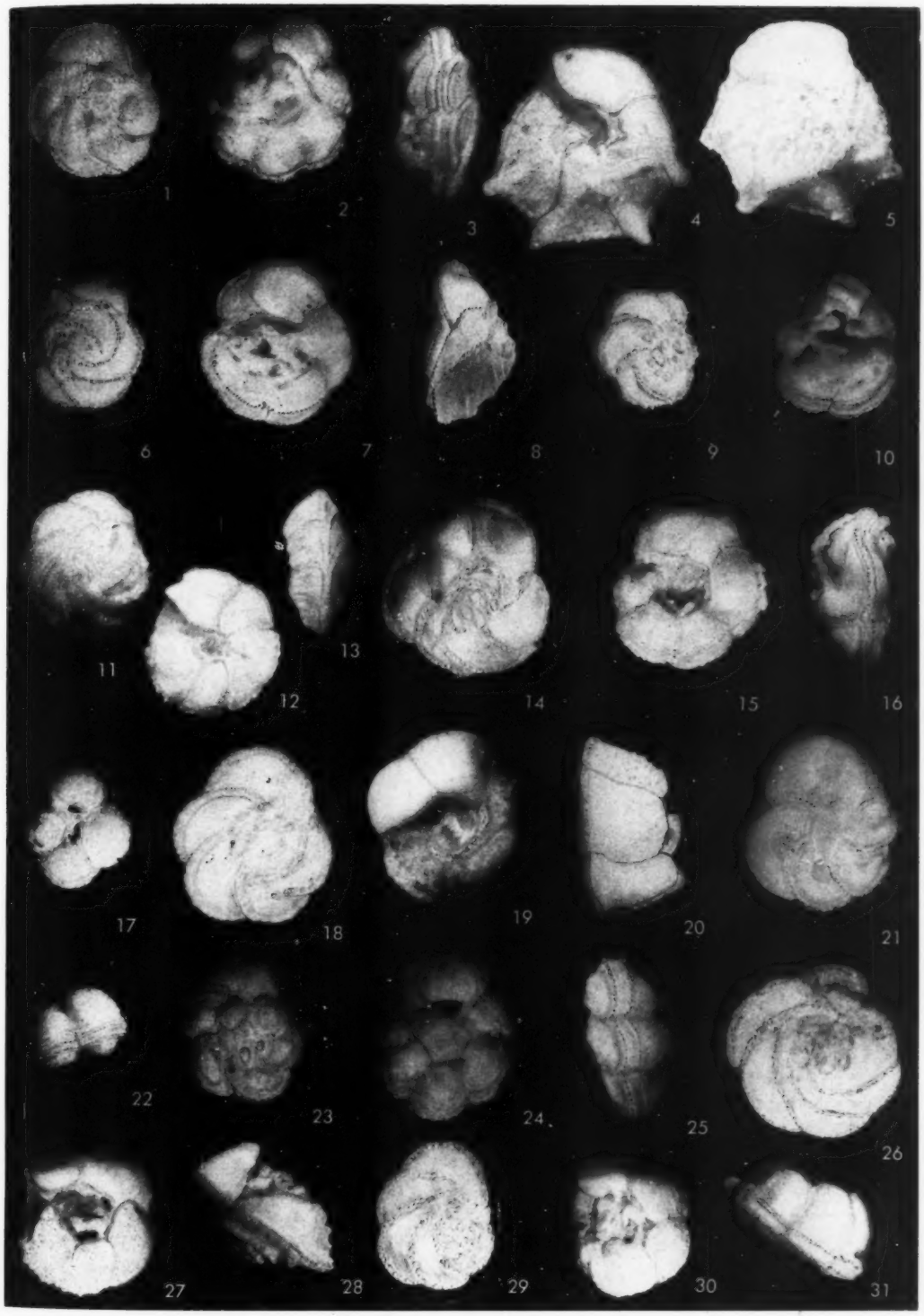
In the following lists the mixed fauna will be reported in two parts for clarity.

Upper Cretaceous fauna:
Globigerina cretacea d'Orbigny
Rugoglobigerina rugosa rugosa (Plummer)
Globigerinella aspera (Ehrenberg)
Globorotalia velascoensis (Cushman)
Globotruncana arca (Cushman)
G. calcarata Cushman
G. caliciformis (de Lapparent)
G. canaliculata (Reuss)
G. contusa (Cushman)
G. fornicata Plummer
G. gansseri Bolli
G. globigerinoides Brotzen
G. marginata (Reuss)
G. rosetta (Carsey)

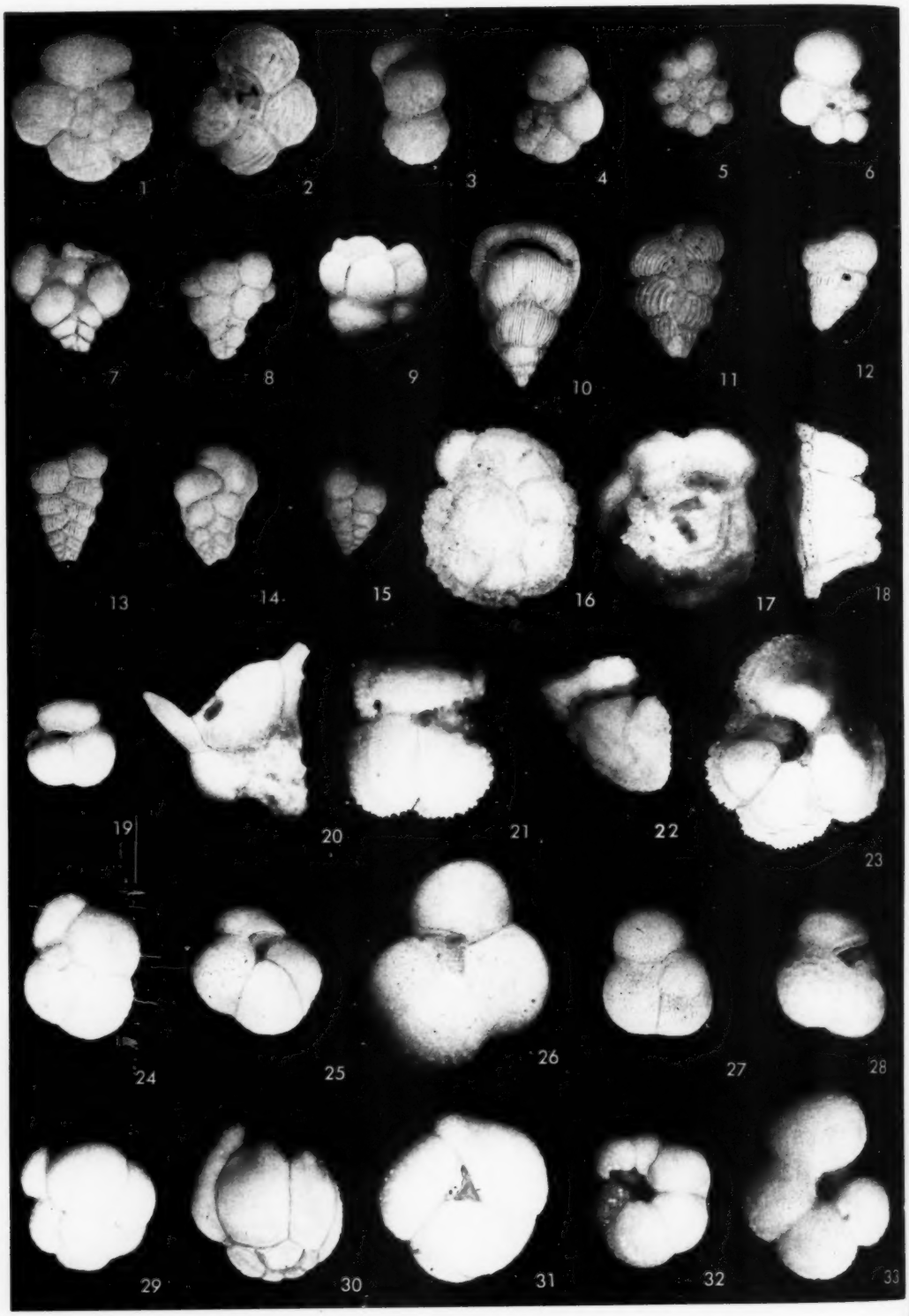
EXPLANATION OF PLATE 29

Species of *Globotruncana* from MP 27; 19° 34′ N. Latitude, 171° 54′ W. Longitude; depth 2050 fathoms.

FIGS. *1–3—Globotruncana arca* (Cushman). Three specimens; *1*, dorsal view, ×48; *2*, ventral view, ×46; *3*, side view, ×51. (p. 231)
4, 5—Globotruncana calcarata Cushman. *4*, ventral view; *5*, dorsal view; ×52. (p. 232)
6–8—Globotruncana caliciformis (de Lapparent). Three specimens; *6*, dorsal view; *7*, ventral view; *8*, side view; ×47. (p. 232)
9, 10—Globotruncana canaliculata (Reuss). Two specimens; *9*, dorsal view, ×45; *10*, ventral view, ×53. (p. 232)
11–13—Globotruncana stuarti (de Lapparent). *11*, dorsal view; *12*, ventral view; *13*, side view; ×53. (p. 233)
14–16—Globotruncana contusa (Cushman). Three specimens; *14*, dorsal view; *15*, ventral view *16*, side view; ×46. (p. 232)
17, 22—Globotruncana globigerinoides Brotzen. Two specimens; *17*, ventral view; *22*, side view; ×48. (p. 233)
18–20—Globotruncana gansseri Bolli. Three specimens; *18*, dorsal view; *19*, ventral view; *20*, side view; ×53. (p. 232)
21—Globotruncana fornicata Plummer. Dorsal view; ×46. (p. 232)
23–25—Globotruncana marginata (Reuss). Three specimens; *23*, dorsal view; *24* ventral view; *25*, side view, ×46. (p. 233)
26–28—Globotruncana rosetta (Carsey). Three specimens; *26*, dorsal view; *27*, ventral view; *28*, side view; ×45. (p. 233)
29–31—Globotruncana ventricosa (White). Three specimens; *29*, dorsal view; *30*, ventral view; *31*, side view; ×47. (p. 233)



Hamilton, Foraminifera from Pacific seamounts



Hamilton, Foraminifera from Pacific seamounts

G. stuarti (de Lapparent)
G. ventricosa (White)
Gümbelina costulata Cushman
G. excolata Cushman
G. globulosa (Ehrenberg)
G. striata (Ehrenberg)
G. plummerae Loetterle
G. pseudotessera Cushman
G. ultimatumida White
Pseudotextularia varians Rzehak
Ventilabrella austinana Cushman
V. carseyae Plummer

Early Tertiary to Recent fauna:

In addition to the modern tropical Pacific species previously noted (see "present-day fauna") the following Tertiary planktonic species have been identified.

Globigerina altispira Cushman and Jarvis
G. bulloides d'Orbigny
G. cretacea d'Orbigny
G. pseudobulloides Plummer
G. triloculinoides Plummer
G. venezuelana Hedberg
Globigerinella voluta (White)
Globigerinoides mexicana (Cushman)
Globorotalia aragonensis Nuttall
G. crassata (Cushman)
G. crassata (Cushman) var. *aequa* Cushman and Renz
G. crassata densa (Cushman)
G. velascoensis (Cushman)
G. velascoensis (Cushman) var. *acuta* (Toulmin)
G. wilcoxensis Cushman and Ponton
Hantkenina alabamensis Cushman
Sphaeroidinella multiloba LeRoy
S. rutschi Cushman and Renz
S. seminulina (Schwager)
Eponides trümpyi Nuttall

Hess Guyot faunas.—Hess Guyot[1] (indicated as shallow sounding on U. S. Navy H. O. Chart No. 0528 at 17°45′N. Lat. and

[1] Hess Guyot is named after Harry H. Hess of Princeton University who discovered it.

EXPLANATION OF PLATE 30

Species (in addition to those in Plate 29) from the mixed Upper Cretaceous to Recent fauna from MP 27.

FIGS. *1–3—Rugoglobigerina rugosa rugosa* (Plummer) Bronnimann. Three specimens; *1*, dorsal view; *2*, ventral view; *3*, side view; ×51. (p. 227)
4—Nonion micrus Cole; ×51. (p. 236)
5—Globigerinella aspera (Ehrenberg); ×53. (p. 226)
6—Globigerinella voluta (White); ×51. (p. 227)
7—Ventilabrella austinana Cushman; ×51. (p. 235)
8—Ventilabrella carseyae Plummer; ×51. (p. 235)
9—Pseudotextularia varians Rzehak; ×56. (p. 235)
10—Gümbelina plummerae Loetterle. Side view; ×54. (p. 234)
11—Gümbelina excolata Cushman. Front view; ×51. (p. 234)
12—Gümbelina costulata Cushman. Front view; ×51. (p. 234)
13—Gümbelina striata (Ehrenberg). Front view; ×51. (p. 235)
14—Gümbelina pseudotessera Cushman. Front view; ×51. (p. 234)
15—Gümbelina globulosa (Ehrenberg). Front view; ×50. (p. 234)
16—18—Globorotalia velascoensis (Cushman). Three specimens; *16*, dorsal view; *17*, ventral view; *18*, side view; ×52. (p. 231)
19—Globigerina triloculinoides Plummer. Ventral view; ×51. (p. 223)
20—Hantkenina alabamensis Cushman. Side view of fragment; ×55. (p. 229)
21, 22—Globorotalia crassata (Cushman) var. *aequa* Cushman and Renz. Two specimens; *21* ventral view; *22*, dorsal view; ×52. (p. 230)
23—Globorotalia velascoensis (Cushman). Ventral view of specimen from Hess Guyot; ×48. (p. 231)
24, 25—Sphaeroidinella rutschi Cushman and Renz. Two specimens; *24*, dorsal view, ×53; *25*, ventral view, ×50. (p. 228)
26—Sphaeroidinella multiloba LeRoy. Ventral view; ×52. (p. 228)
27, 28—Sphaeroidinella seminulina (Schwager). Two specimens; *27*, dorsal view; *28*, ventral view. ×54. (p. 228)
29, 30—Globigerina altispira Cushman and Jarvis. Two specimens; *29*, side view; *30*, side view. ×55. (p. 220)
31—Globigerina venezuelana Hedberg. Ventral view; ×59. (p. 223)
32—Globigerina subcretacea Lomnicki. Ventral view; ×53. (p. 223)
33—Globigerina bulloides d'Orbigny. Ventral view; ×53. (p. 221)

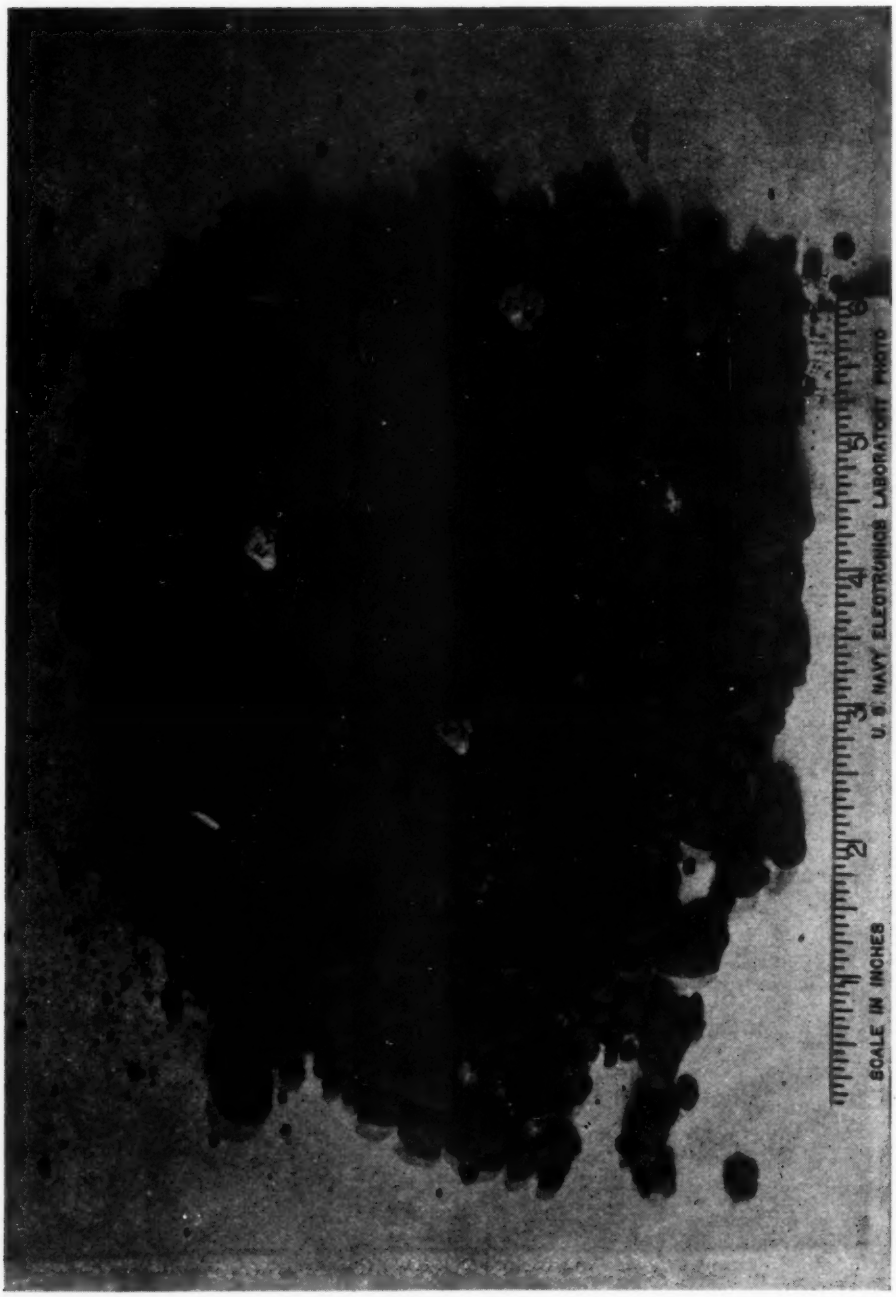


FIG. 2—Basaltic gravel and sand mixed with red clay and containing a mixed Upper Cretaceous to Recent foraminiferal fauna. Sample taken from the 30½ to 34½ inch division of the core from MP 27-2 from a depth of 2050 fathoms

174°16′W. Long.) is a peak on the south side of the main ridge of the Mid-Pacific Mountains. This guyot has a distinctly flat top with a shallowest sounding of 902 fathoms. At Station MP 33 C near the center of this flat-topped feature the dredge brought up a large amount of rounded, soft, but indurated fossil *Globigerina* ooze which ranged in size from pellets to boulders a foot in length (fig. 3). When this haul came up over the side of the ship there was a stream of milky white water pouring out of the dredge. The fragments of indurated *Globigerina* ooze apparently were rounded in the dredge during the mile long haul to the surface. Scattered remnants of a manganese dioxide crust support this belief.

The indurated *Globigerina* ooze described above yielded an uncontaminated, extremely well-preserved, planktonic assemblage of probable Paleocene age. The following species have been identified:

Globigerina aff. *G. angulata* White
G. bulloides d'Orbigny
G. compressa Plummer
G. cretacea d'Orbigny
G. eocaena Gümbel
G. pseudobulloides Plummer
G. triloculinoides Plummer
Globigerinella pseudovoluta Bandy
Globorotalia crassata (Cushman)
G. aff. *G. inconspicua* Howe
G. velascoensis (Cushman)
G. velascoensis (Cushman) var. *acuta* (Toulmin)
Gümbelina aff. *G. glabrans* Cushman
G. globulosa (Ehrenberg)
G. ultimatumida White
Eponides trümpyi Nuttall

Small pipe dredges with canvas bags attached which trailed behind the main chain-bag were used during three dredge hauls to gather samples of the *Globigerina* ooze. These samples contained the modern Pacific tropical fauna plus the following rare planktonic index fossils:

Globigerinoides mexicana (Cushman)
Globigerina ouachitaensis Howe and Wallace
Globorotalia aragonensis Nuttall
G. crassata (Cushman)
G. velascoensis (Cushman)
G. velascoensis (Cushman) var. *acuta* (Toulmin)

Five cores were taken on Hess Guyot with the Phleger Bottom Sampler. These cores ranged in length from 4¾ inches to a little over 38 inches. At each station the core was essentially composed of the modern Pacific tropical foraminiferal fauna plus the following rare, fossil planktonic index fossils:

Globigerina triloculinoides Plummer
Globorotalia aragonensis Nuttall
G. crassata (Cushman)
G. crassata densa (Cushman)
G. velascoensis (Cushman)
G. velascoensis (Cushman) var. *acuta* (Toulmin)
Gümbelina cubensis Palmer

Faunas on Horizon Guyot.—Horizon Guyot, named after the Scripps motor vessel *Horizon* is a volcanic ridge whose northeast end is indicated on Navy H. O. Chart 0528 at 19°40′N. Lat., 168°32′W. Long. A saddle more than 1200 feet deep divides the ridge near its west end so that the western end appears as an oval seamount. This seamount has a break in slope between the flat top and upper side slopes at depths between 935 and 950 fathoms. Two dredge hauls, one snapper sample and five small cores were taken on Horizon Guyot.

Two cores of particular interest were taken on a 2 degree slope just above the break in slope at the edge of the guyot. Each core contained the same pure Eocene fauna except for the top 1 to 2 inches which contained a mixture of Eocene species and modern tropical Pacific species. The present-day sea bottom on the top of Horizon Guyot therefore is a mixture of Eocene and Recent species. One core (MP 25 E-2) was 28 inches long and was a pure, unconsolidated Eocene *Globigerina* ooze from the bottom to within two inches of the top. The second (MP 25 E-1) was 31 inches long and was the same except that the bottom four inches contained a mixture of Recent and Eocene species similar to the topmost portion. This bottom mixture could have been sampled if the core hit the bottom a second time before withdrawal to the surface, or if the deposit cored was a slump. Both cores were taken at the same station but not at the same place because of drift of the ship on station.

The following Eocene fauna was present

Sample taken from the 30½ to 34½ inch division of the core from MP 27-2 from a depth of 2050 fathoms

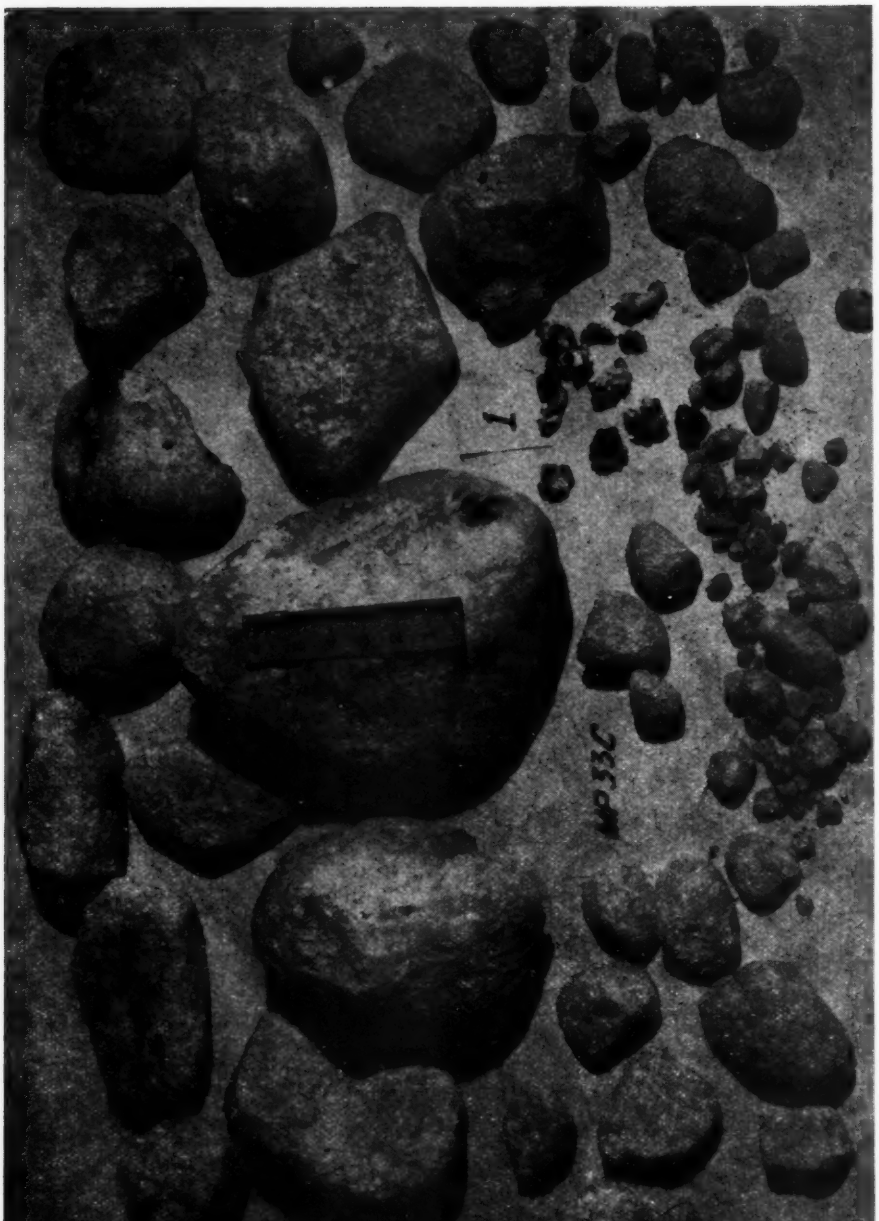


FIG. 3—Dredge haul from the center of the top of Hess Guyot (MP 33 C.) The rounded rocks are composed of soft but indurated *Globigerina* ooze and contain a Paleocene foraminiferal fauna.

in both cores with almost no variation:

Globigerina apertura Cushman
G. bulloides d'Orbigny
G. aff. *G. eocaena* Gümbel
G. linaperta Finlay
G. mckannai White
G. ouachitaensis Howe and Wallace
G. ouachitaensis Howe and Wallace var. *senilis* Bandy
G. orbiformis Cole
G. rotundata d'Orbigny var. *jacksonensis* Bandy
G. triloculinoides Plummer
Globigerinoides nuttalli Hamilton, n. sp.
G. mexicana (Cushman)
Globigerinella pseudovoluta Bandy
Globorotalia aragonensis Nuttall
G. centralis Cushman and Bermudez
G. crassata (Cushman)
G. crassata densa (Cushman)
G. aff. *G. inconspicua* Howe
Gümbelina cubensis Palmer
G. venezuelana Nuttall
Hantkenina mexicana Cushman var. *aragonensis* Nuttall
Hastigerinella eocanica Nuttall
H. eocanica aragonensis Nuttall
Eponides trümpyi Nuttall

The following species were collected from cracks inside manganese-covered boulders of volcanic rock cemented by fine-grained organic limestone which were dredged from the top of Horizon Guyot.

Globigerina triloculinoides Plummer
Globorotalia aragonensis Nuttall
G. crassata (Cushman)
G. crassata densa (Cushman)
G. velascoensis (Cushman)
G. velascoensis (Cushman) var. *acuta* (Toulmin)
Gümbelina cubensis Palmer
G. globulosa (Ehrenberg)
Sphaeroidinella seminulina (Schwager)

Faunas of Cape Johnson Guyot.—Cape Johnson Guyot, named after the USS *Cape Johnson*, the ship which took the original soundings resulting in the discovery of both Hess and Cape Johnson Guyots, is a flat-topped peak on the south side of the main ridge of the Mid-Pacific Mountains. Its position is indicated as a shallow sounding on the Navy H. O. Chart 0528 at 17°05′N. Lat. and 177°15′W. Long. The shallowest sounding was 925 fathoms near the center of the flat top.

Four cores of *Globigerina* ooze ranging in length from 10 inches to 108 inches were taken by the Phleger Bottom Sampler and piston corer at each of four stations just above and below the break in slope and near the center of Cape Johnson Guyot. Each core was essentially composed of modern tropical Pacific species, but in each fossil planktonic Foraminifera are rare. The fossil specimens usually could be distinguished by their brownish-white color in contrast to the white color of most of the Recent species.

The following fossil species were observed in these Cape Johnson cores:

Globigerina altispira Cushman and Jarvis
G. apertura Cushman
G. linaperta Finlay
G. triloculinoides Plummer
G. venezuelana Hedberg
Globorotalia aragonensis Nuttall
G. crassata (Cushman)
G. velascoensis (Cushman)
G. velascoensis (Cushman) var. *acuta* (Toulmin)
Gümbelina cubensis Palmer
G. globulosa (Ehrenberg)

The following fossil planktonic species were taken from cracks inside manganese dioxide coated limestone rocks dredged from Cape Johnson Guyot:

Globorotalia crassata (Cushman)
G. velascoensis (Cushman)
G. velascoensis (Cushman) var. *acuta* (Toulmin)

Fauna on Guyot 19171.—Guyot 19171 (numbered after the nearest lines of latitude and longitude) is indicated as a shallow sounding on the Navy H. O. Chart No. 0528 at 19°25′ N. Lat. and 171°00′W. Long. It has a flat top on which the shallowest sounding was 668 fathoms.

A dredge haul (MP 26A-3) across the break in slope brought up a rounded boulder of indurated *Globigerina* ooze completely covered by a manganese coating which was 6 mm. thick on top, but on the bottom was merely a black discoloration.

This indurated *Globigerina* ooze boulder has a planktonic lower Eocene fauna the tests of which were affected by solution and reprecipitation. The following species have been identified:

Globigerina triloculinoides Plummer
Globorotalia aragonensis Nuttall

G. centralis Cushman and Bermudez
G. crassata (Cushman)
G. crassata densa (Cushman)
G. wilcoxensis Cushman and Ponton

DISCUSSION OF RESULTS AND CONCLUSIONS

Globotruncana —*Globotruncana* Cushman, 1927, is an extinct genus of Foraminifera with a world-wide distribution. The species are considered to be the best foraminiferal index fossils of the Upper Cretaceous. Beds containing *Globotruncana* probably are not older than Cenomanian, and all species of the genus die out at the end of the Maestrichtian according to Glaessner (1945). *Globotruncana* species are found in the Tethyan Province in Mexico, the Caribbean and Gulf Coast and adjacent regions, the Alps, Apennines, North Africa, Southeastern Africa, Greece, Caucasus, the Middle East, New Guinea, Celebes, Australia and New Zealand, and have recently been reported from California (Glaessner, 1945; Thalmann, 1934 and 1942a; Bandy, 1951). The genus is considered to have been planktonic due to its common occurrence with species of *Globigerina* and *Globorotalia* (Glaessner, 1945) and its form of large, frequently inflated chambers. The abundance of species of *Globotruncana* in places where purely planktonic assemblages are likely to occur (as in the Mid-Pacific guyot area) is important evidence of its existence as a planktonic organism.

Globotruncana is closely allied to *Globorotalia* and *Globigerina* (Cushman, 1948). *Globigerina rugosa* Plummer with its umbilical plate and *Globotruncana globigerinoides* Brotzen which is no more than a double-keeled *Globigerina* are intergrading forms between *Globigerina* and *Globotruncana* which occur in the Mid-Pacific faunas and clearly illustrate the evolution of *Globotruncana* from *Globigerina*.

Species of *Globotruncana* are assumed to have been tropical and semi-tropical forms because of their occurrence in the Cretaceous Tethys Sea which is known to have been a warm water area due to common occurrences of reef coral.

Species of *Globotruncana* which are of common occurrence in the cores at MP 27 are also common in Mexico, the Gulf Coast and Caribbean regions (Cushman, 1946). This is additional evidence of the close faunal affinity of the Cretaceous guyots faunas with those of the Gulf Coast and adjacent regions (which is in accord with the conclusions reached regarding the megafossils) and which is further proof of the presence of the Tethys Sea across Mexico and Central America.

The age of the guyot *Globotruncana* is Campanian-Maestrichtian. The overlapping ranges of the identified species are shown in the range chart (fig. 4).

Gümbelina.—*Gümbelina* Egger, 1899, is an extinct genus with world-wide distribution in the tropical and semi-tropical Tethys Sea. The genus occurs commonly in Upper Cretaceous beds where the striate forms die out at the end of the Maestrichtian; the genus persisted into the Tertiary and finally died out in Oligocene time. Cushman (1938) and Glaessner (1945), among other authors, think that *Gümbelina* was a pelagic form because of its thin-walled and globular chambers and its common occurrence in planktonic faunas with *Globigerina* and *Globorotalia*, the genera making up the vast bulk of modern pelagic deposits.

Three groups of species of *Gümbelina* are known from the Mid-Pacific guyots. The oldest is from the cores at MP 27. This fauna contains many species which occur in the Gulf Coast and adjacent regions in the Upper Cretaceous. These species of *Gümbelina* occur with the species of *Globotruncana* discussed previously and are of the same age.

The second group of species of *Gümbelina* occurs in the Paleocene *Globigerina* ooze from Hess Guyot. *Gümbelina ultimatumida* White is abundant and *G. globulosa* (Ehrenberg) is common. The third group of species occurs in the Eocene cores from Horizon Guyot. In these cores the minute Eocene forms of *Gümbelina cubensis* Palmer and *G. venezuelana* Nuttall are abundant.

Hantkenina.—*Hantkenina* Cushman, 1925, is an extinct genus with world-wide distribution in the Eocene Tethys Sea (Bronniman, 1950). The genus occurs in marls, shales, and limestones and is thought to have been a planktonic form (Thalmann, 1942b; Bronniman, 1950). The typically

inflated chambers suggest a planktonic organism.

The range of the genus is noted by authors (Cushman, 1948; Glaessner, 1945) as Eocene to lower Oligocene, but Bronnimann (1950) and Thalmann (1942c) exclude the Oligocene occurrences and believe that the genus is restricted to Eocene deposits.

A species of *Hantkenina* occurs in the cores from Horizon Guyot together with other lower-middle Eocene species. This species of *Hantkenina* has spines situated in prolongation of the chamber axis which is a primitive characteristic of the genus. The species appears to be *H. mexicana* Cushman var. *aragonensis* Nuttall which is diagnostic of lower and middle Eocene. One broken specimen of *Hantkenina alabamensis* Cushman was found in the Cretaceous-Recent fauna.

Globorotalia velascoensis (*Cushman*).—This species was described by Cushman in 1925 from the Velasco shale of the Tampico Embayment area of Mexico. In the Velasco shale it is the most abundant species and is thought by Cushman (1927) to have been the dominant planktonic species of Foraminifera during Velasco time. Grimsdale (1951) states that "*Globorotalia velascoensis* is not found in the oldest layers of the Velasco formation in eastern Mexico. Nor does it reach down as far as the base of the Tertiary column in Syria." The species has been reported from the Upper Cretaceous of Mexico, Cuba, Trinidad, and Florida; and from the Paleocene and Eocene of Mexico, the Caribbean and Gulf Coast areas, and the Middle East. Muir (1936) reports this species was found in the Tampico Embayment region of Mexico with *Globotruncana arca*, the distinctive Upper Cretaceous species which died out at the end of the Maestrichtian. There is a great variation in the group of forms from which *Globorotalia velascoensis* was described and misidentifications (from the type species) are common in the literature. It appears safest, pending a close study of this form by someone having access to type material, to extend the known range from the Upper Cretaceous to the lower Eocene.

Globorotalia velascoensis (Cushman) appears to be a good planktonic index fossil for the Pacific area. It is found in the Mid-Pacific guyot area in the indurated ooze on Hess Guyot where it is the dominant species; and from Guyot 19171, and Horizon and Cape Johnson Guyots.

Globorotalia aragonensis *Nuttall*.—This species was described from the Aragon formation (Eocene) of Mexico and has been widely reported in the Caribbean and Gulf of Mexico areas and the Middle East. It is thus a world-wide index fossil with a geologic range reported to be lower and middle Eocene. It is very common in the Mid-Pacific guyot area and occurs on all five guyots sampled. *G. aragonensis* occurs with *G. velascoensis* in many of the *Globigerina* ooze cores which are otherwise the modern Pacific tropical planktonic fauna. In none of the pure assemblages do the two species occur together. Of all of the species of *Globigerina* and *Globorotalia* present in the fossil faunas *G. velascoensis* and, especially, *G. aragonensis* must be considered the most important and widespread in the guyot area of the Mid-Pacific Mountains.

The Cretaceous planktonic foraminiferal fauna of MP 27 is a well integrated Campanian-Maestrichtian assemblage and is very closely related to faunas of the same age from the Gulf Coast, Caribbean and adjacent areas (upper Taylor-lower Navarro, Cushman, 1946). It is a typical assemblage of the tropical to semi-tropical Tethyan Province. The range chart (fig. 4a) indicates the overlapping ranges of the species involved in this age determination. It should be noted here that because the fauna described from MP 27-2 is mixed it cannot be assumed that all of the species listed in the Upper Cretaceous faunal list existed at the same time. It is necessary here to establish a lower time range for the beginning of this mixed fauna. Overlapping ranges of the more abundant index species (*Globotruncana arca*, *G. caliciformis*, *G. contusa*, *G. fornicata*, *G. marginata*, *G. rosetta*, *G. ventricosa*, *Gümbelina costulata*, *G. plummerae*, and *G. excolata*) plus other less abundant species such as *Globotruncana gansseri* and *G. stuarti* indicate that the older elements of the mixed fauna are upper Campanian-lower Maestrichtian (upper Taylor-lower Navarro of the Gulf Coast) with a lower Maestrichtian age the most probable.

The piston-type core of MP 27 at 2050 fathoms in a basin below the slopes of Guyot 2071 has been previously noted, but the anomalous layers of gravel and the mixed Cretaceous to Recent fauna require further discussion.

Sand and gravel in deep sea deposits away from obvious sources may be due to several causes; among these are submarine slumps, landslides, mudflows, and turbidity currents. In recent years increasing attention has been paid to submarine transportation of coarse sediments and there is a growing body of literature on the subject. Turbidity currents, especially, are being studied and discussed (Turbidity currents and the transportation of coarse sediments to deep water, A Symposium, SEPM Spec. Pub. No. 2). Some of the causes for the start of a submarine landslide, slump, or mudflow which might turn into a turbidity current may be the triggering action of earthquakes, storm waves, tsunamis, tidal forces, excessive compaction rates, and deposition of slopes in excess of maximum angle of repose for the material concerned.

Kuenen (1951) favors slumping as the cause of turbidity currents in submarine canyons from slopes of 15 to 20 degrees (about those of the guyots). Menard and Ludwick (1951) believe that submarine landslides in unlithified sediments are the only likely source of dense turbidity currents thus far suggested.

In core MP 27-2 there are layers of sand and gravel separated by *Globigerina* ooze and red clay in which the constituent grains are both graded and ungraded. The bottom layer of gravel in MP 27-2 is definitely graded. Kuenen (1950) reported that graded bedding was typically the end result in his turbidity current experiments.

Slumps and landslides do not have graded bedding; this fact together with the presence of the gravel in a basin some distance away from the guyots (which are the presumed source) suggests that the sand grains, pebbles, and cobbles of basalt arrived in the basin due to transportation by turbidity current.

The conditions noted in core MP 27-2 could have occurred as follows:

(1) Erosional debris deposited on the slopes of a nearby guyot at an angle near the maximum angle of repose for the sand and gravel concerned.

(2) The start of a submarine landslide on the slopes due to triggering by some cause.

(3) The movement of the above material down slope for a long distance during which the surrounding water became mixed with the slide causing a turbidity current of high density which may have rolled large pebbles and cobbles along the bottom (as suggested by Menard and Ludwick, 1951).

(4) The arrival and deposition of this material in the basin at MP 27.

(5) The mass sliding of coarse material on the sides of the guyot could have started a series of slides and slumps which followed each other into the basin to cause the complex conditions postulated by Menard and Ludwick.

(6) At a later time other turbidity currents could have brought down coarse material from other parts of the slopes (material possibly made more unstable by the earlier removals of material) or even from other unknown guyots in the area, which formed higher layers in the bottom sediments.

The occurrence of red clay between the layers of gravel does not necessarily imply the great time intervals normally required for red clay deposition (about 1000 years per cm.). Disruption of the bottom sediments would have caused a relatively large concentration of red clay in the bottom waters in and out of the turbidity currents. This clay would fall to the bottom and form thicker layers faster than is normal.

An important point which tends to confirm the above sequence of events is the mixed Cretaceous to Recent foraminiferal fauna which is found from the top one inch to the bottom of the cores. Prior to the start of slumping or sliding there would have been a deposition of normal faunas in continuous sequence from old to young on the slopes of the guyots. If the tops and upper sides of the guyots are essentially areas of nonaccumulation (discussed further below) then the result might well be a thin bed which included species of the Upper Cretaceous, Tertiary, and Recent. The Cretaceous fauna found in the gravel layers was probably at that time the planktonic fauna

which was deposited with the gravel. When the submarine landslide, or slump, began to move and turned into a turbidity current, the whole mass of sediment together with its foraminiferal fauna became mixed. This mixture of Cretaceous to Recent species settled out in the basin to form the mixed fauna which was obtained in cores at MP 27.

The occurrence of restricted Upper Cretaceous species at the surface of the present sea bottom may be explained in at least two ways: (1) the sequence of events postulated above occurred quite recently and normal planktonic deposition has not buried the newly deposited material, or (2) the events occurred in the geologic past and the basin of deposition is an area of nonaccumulation due to deep currents. The configuration of the Mid-Pacific Mountains in the area in question is such that it might cause a restriction and funneling of currents through the basin, although such deep currents (at 2000 fathoms) are unknown.

The assemblage from the indurated ooze of Hess Guyot calls for further discussion. The planktonic fauna is most closely related to that from the Velasco shale of Mexico. The geologic age of the Velasco shale has been a subject of controversy for many years. Muir (1936) discussed this problem at some length and concluded together with White, Cushman, Plummer and Trager (all quoted in Muir, 1936) that the Velasco shale is uppermost Cretaceous. Nuttall (1930) thinks that the Velasco is Upper Cretaceous and Paleocene. Thalmann (1935) believed the Velasco fauna to be Paleocene as did Barker (1936) and Grimsdale (1947). Present day work in the oil fields of the Tampico Region (Salas, 1949) indicates that the Velasco formation is equivalent to the Midway (Paleocene) of the Gulf Coast Region. Noth (1951) summarizes the whole problem and concludes that "From these data we get the impression that the Velasco shales were deposited during a period which extended from the uppermost Cretaceous through the Paleocene and finally into the Eocene. It appears that the deposition of the Velasco did not start simultaneously everywhere. This might be the reason why this group is dated differently by various authors." White (personal communication, Dec. 4, 1951) stated "—Noth's comments—appear to my recollection as stating the case much to my satisfaction especially when it is remembered that I dealt only with the lower Velasco which appeared to involve transition from Cretaceous to Eocene. In those days Paleocene was a new term which in my opinion had not been properly established but whose equivalents were involved in the Velasco and thus then generally considered as Cretaceous."

The occurrence of *Eponides trümpyi* Nuttall, *Gümbelina globulosa* (Ehrenberg), *Gümbelina ultimatumida* White, common *Globigerina triloculinoides* Plummer, and *Globigerina compressa* Plummer together with a flood of *Globorotalia velascoensis* (Cushman) all argue for a Paleocene age for the indurated ooze of Hess Guyot. It is the writer's opinion that this sediment is older than the Eocene oozes on Horizon Guyot and is probably upper Paleocene (upper Midway).

Concerning the geologic history of the faunal sequences of Foraminifera, Glaessner (1945) notes that in the Caucasus, Apennines, Alps, and Pyrenees, the *Globotruncana* marls (Senonian) are followed by *Globigerina* and *Gümbelina* marls of Danian age which are in turn succeeded by Paleogene deposits rich in *Globorotalia*. Glaessner also notes this change in Mexico at the boundary of the Mendez and Velasco formations and also in Egypt, Palestine, Iraq, and Turkey. The Danian is thus a transition period before a new microfaunal cycle takes place in the Paleocene with *Globorotalia* taking the place of *Globotruncana*. Glaessner also notes that the rapid evolutionary sequence *Globorotalia velascoensis-G. aragonensis-G.* aff. *G. crassula* corresponds generally to the time interval Danian and Paleocene-lower Eocene-middle and upper Eocene. These faunal sequences as noted above by Glaessner are arguments for a Paleocene age of the indurated ooze of Hess Guyot which is dominated by *Globorotalia velascoensis*.

On Horizon Guyot, as previously noted, there is a pure unindurated fossil *Globigerina* ooze just beneath the surface although the surface species are a mixture of fossil and Recent species. This fossil ooze contains

Globorotalia aragonensis Nuttall, *Hantkenina mexicana* Cushman var. *aragonensis* Nuttall, *Eponides trümpyi* Nuttall, *Hastigerinella eocanica aragonensis* Nuttall, and other forms which are typical of the Aragon formation of the Tampico region of Mexico. Bermudez (1950) correlates the Aragon formation with the upper Wilcox. Salas (1949) correlates the Aragon with the lower Claiborne. The overlapping ranges of the species of the Horizon Guyot fauna together with its closeness to the Aragon fauna make an age determination of upper Wilcox-lower Claiborne about right. Expressed in broader terminology the age would be early to middle Eocene.

The sequences of foraminiferal faunas noted by Glaessner and discussed above can be recognized in the faunas of the Mid-Pacific guyots. Upper Cretaceous planktonic Foraminifera dominated by species of *Globotruncana* and *Gümbelina* were deposited among the eroded gravels on the side slopes of one of the guyots; at a later date planktonic Paleocene and Eocene Foraminifera, dominated by species of *Globorotalia* were deposited on the tops of three of the guyots. Older Foraminifera could easily be present on the tops of the guyots but their existance cannot be established because the abraded platform was not reached in any of the cores.

It should be noted that the Foraminifera, quite independently of the megafossils, date the erosion of at least one guyot as pre-Late Cretaceous (fauna in the gravel at MP 27) and the age of one of the flat tops as pre-late Cretaceous-Paleocene and the age of the flat tops of two other guyots as pre-early Eocene.

It is known that the Tethyan Province of the Cretaceous and early Tertiary was tropical to semi-tropical due to the occurrence of reef coral. The genera *Globotruncana* and *Hantkenina* apparently were confined to the Tethyan Province and adjacent areas and can thus be considered to have been Foraminifera of the then tropical to semi-tropical waters. The occurrence of these genera on the Mid-Pacific guyots affirms that the area was still covered by warm waters in the Upper Cretaceous and early Tertiary as was the situation when the reef coral-rudistid fauna grew on the tops of the ancient islands at an earlier date in the Cretaceous.

SEDIMENTATION OF *Globigerina* OOZE ON THE GUYOTS

Most authors define *Globigerina* ooze as a sea bottom deposit containing more than 30% calcium carbonate in the form of tests of Foraminifera. The ooze is milky white, rose, yellow or brown; it is found at all depths down to about 3000 fathoms although the average maximum depth is around 2400 fathoms; *Globigerina* ooze covers approximately 47% of present day sea bottoms. (Kuenen, 1950); it is thought to be accumulating at a rate of about 1 cm. per 632 years (Shepard, 1948). The main constituents of *Globigerina* ooze are those planktonic Foraminifera which live in the pelagic realm, and plates from Coccolithophoridae. Revelle (1944) suggests the name "calcium carbonate ooze" if the material is largely fine-grained and not in the form of recognizable skeletal fragments.

Globigerina ooze may be absent at great depths apparently because of solution of calcium carbonate on the bottom and as the tests settle through the water column. Kuenen (1950) stresses the solvent action of cold bottom waters deficient in calcium carbonate as a reason for the absence of calcareous sediments at great depths.

The production of planktonic Foraminifera occurs in offshore water masses, especially those of the tropical and semi-tropical seas. *Globigerina* ooze accumulates where these tests are not diluted by other sediments. The occurrence of planktonic oozes in oceanic water masses is therefore no indication of deep water but rather of distance from a source of clastic sediment and/or the absence of other organisms which might mask the deposits. *Globigerina* ooze will accumulate at shallow depths, and on seamounts, and banks unless removed by waves or currents. The only implication as to depth, as far as the *Globigerina* ooze is concerned, is that the guyots were below the surface of the sea and probably below the surface zone of profuse bottom life when the Foraminifera settled to the bottom.

Shepard (1948), Ladd and Tracey (1949), and others have stated that fine sediment does not accumulate on topographic highs

on the sea floor due to removal by waves and currents. The findings of MidPac reveal that this is essentially true on the Mid-Pacific guyots. Although *Globigerina* ooze was sampled on all five of the guyots studied the quantity does not appear to be commensurate with the time these bottom features have been submerged.

The top of a guyot appears to be another example of a topographic high on the sea floor which is essentially an area of non-accumulation due to the removal of fine pelagic sediments by currents. Possible evidence for this statement comes from two sources. It appears to the writer that if pelagic sediments had been allowed to pile up unhindered since the Cretaceous that the flat tops would tend to assume a conical shape; the topmost part formed of *Globigerina* ooze. Secondly, the presence of Paleocene and Eocene Foraminifera at the surface on Hess and Cape Johnson Guyots (mixed with Recent fauna) imply that ancient accumulations of *Globigerina* ooze are exposed and their submarine erosion furnishes fossil Foraminifera which are redeposited with the slow rain of present day planktonic Foraminifera. The presence of pure, unconsolidated Eocene *Globigerina* ooze an inch or two beneath the surface of Horizon Guyot is particularly significant. These deposits of early Tertiary oozes may have accumulated initially in hollows, small erosion channels, and among the rocks. When the bank became essentially level, currents and slumping then kept the top as an area of almost no accumulation. Thus the date of fossil sediments at or near the surface may indicate the time when the bank became essentially flat, practically ceased to accumulate sediments, and planktonic forms deposited later were in large part drifted off the guyot by weak currents, aided possibly by intermittent slumping. The presence of extensive deposits of *Globigerina* ooze on the guyots indicates that there is no present-day erosion of the basaltic platforms (as pointed out by Kuenen, 1950).

The nine-foot core of *Globigerina* ooze taken just below the break in slope on Cape Johnson Guyot (composed of late Tertiary species with rare lower Tertiary index species) indicates that at least in places, the *Globigerina* ooze accumulates to a significant thickness. This nine-foot core may not represent normal planktonic deposition. Sediments deposited on the top of the guyot may have been swept off and have accumulated just below the break in slope where this long core was taken.

Two pictures taken on Sylvania Seamount (a guyot just northwest of Bikini Atoll) probably illustrate the typical occurrences of *Globigerina* ooze on a guyot. One shows an unbroken expanse of ooze. The other shows *Globigerina* ooze on and among manganese-coated rocks. The presence of oscillatory ripple marks in the area photographed, at a depth of 745 fathoms, indicates that deep submarine water movements exist. Menard (in press) suggests that internal waves may be a possible agent.

Indurated *Globigerina* ooze was dredged on four of the guyots. Murray and Lee (1909) record three instances (one each by the *Albatross*, *Challenger* and *Britannia*) in which hardened *Globigerina* ooze was dredged from the sea floor. On the Mid-Pacific guyots the material occurs as dry, hard, calcium carbonate ooze cemented by calcite and usually coated, at least in part, by manganese dioxide. On Hess Guyot the material was Paleocene and on Guyot 19171 it was Eocene in age. Evidence at hand is insufficient to explain the occurrence of this hardened ooze but a possible explanation might be compaction under overlying sediments, followed by reduction in water content and precipitation of calcium carbonate as a cementing material. Later removal of the unconsolidated overlying material would leave the hardened material at the surface where it could become coated with manganese dioxide.

PLANKTONIC INDEX SPECIES OF THE PACIFIC BASIN

As a result of the discovery of the fossil planktonic assemblages on the Mid-Pacific guyots it is now possible to construct a range chart of index fossils of planktonic Foraminifera for the whole tropical and semi-tropical Pacific Basin. In view of the fact that the location of these fossil oozes was in the Middle Pacific, and the fact that they were planktonic assemblages drifted by the currents, it is a safe conclusion that

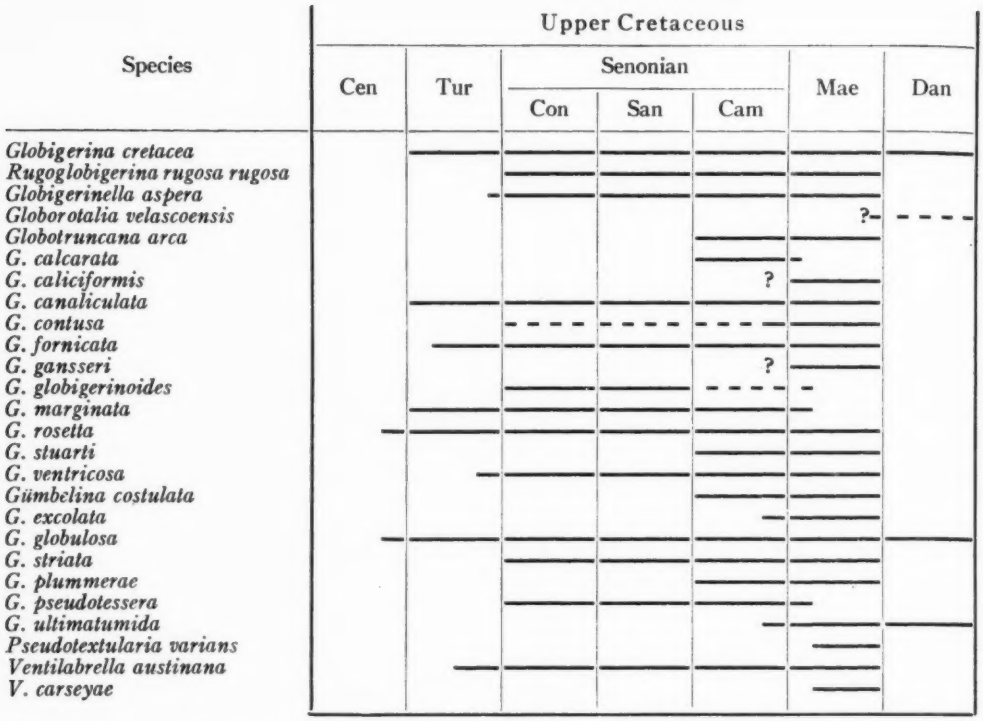


FIG. 4a.—Upper Cretaceous planktonic index fossils from the Mid-Pacific area. World-wide ranges are indicated from referenced literature. Stages of Upper Cretaceous are: Cen: Cenomanian; Tur: Turonian; Con: Coniacian; San: Santonian; Cam: Campanian; Mae: Maestrichtian; Dan: Danian.

the fossil Foraminifera were present during their lifetime all over the tropical and semi-tropical Pacific Basin. This is not surprising, nor unusual, but this is the first report of the occurrence of most of these forms from the deep Pacific Ocean. Their presence could have been logically postulated and predicted, but it is satisfying to know for a fact that they were actually deposited and that they are available to date Pacific sediments and to help solve problems of sedimentation in future work.

Most of the key planktonic index fossils of the Mid-Pacific guyots are listed on the accompanying range chart (fig. 4) together with their known geologic ranges in other areas which was the basis of the age dating of this paper.

SYSTEMATIC DESCRIPTIONS

All type material will be deposited in the U. S. National Museum, Washington, D. C.

Family GLOBIGERINIDAE
Genus GLOBIGERINA d'Orbigny, 1826
GLOBIGERINA ALTISPIRA Cushman and Jarvis, 1936
Plate 30, figs. 29–30

Globigerina altispira CUSHMAN and JARVIS, 1936, Cushman Lab. For. Res. Contr., vol. 12, pt. 1, p. 5, pl. 1, figs. 13, 14.

This species appears to be a good index fossil of the upper Oligocene to upper Miocene. It is reported from the Miocene of Jamaica and Haiti, and from the Miocene and upper Oligocene of the Dominican Republic. Grimsdale (1951) reports this species also from the Miocene of the Middle East. This species occurs rarely in the cores from MP 27.

GLOBIGERINA APERTURA Cushman, 1918
Plate 32, fig. 12

Globigerina apertura CUSHMAN, 1918, U. S. Geol. Survey Bull. 676, p. 57, pl. 12, fig. 8.

This species has been reported from the

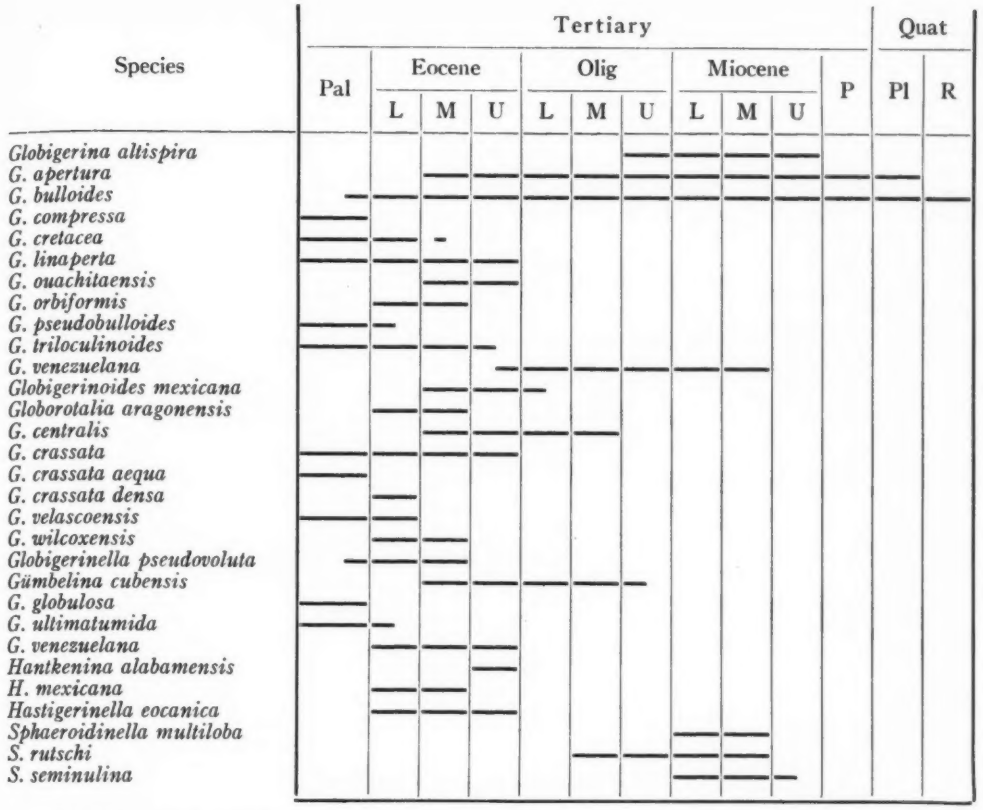


FIG. *4b*.—Some of the Tertiary planktonic index fossils from the Mid-Pacific area. World-wide ranges are indicated from literature cited and the evidence of this paper.

Eocene of Mexico, the Oligocene of Cuba and Mexico, the Miocene of the Atlantic Coastal Plain, the Pliocene and Pleistocene of California. The writer has seen no reference in modern literature that this species has lived in the Recent. *G. apertura* might be a good planktonic index fossil which lived in the Pleistocene but not the Recent and would thus be a valuable form, in some cases, for differentiating the Pleistocene and Pliocene from Recent.

GLOBIGERINA BULLOIDES d'Orbigny, 1826
Plate 30, fig. 33; plate 31, figs. 26–27; plate 32, fig. 25

Globigerina bulloides D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 277, no. 1; Modeles no. 76 and young, no. 17.
Globigerina bulloides d'Orbigny, PHLEGER and PARKER, 1951, Geol. Soc. America Mem. no. 46, p. 34, pl. 19, figs. 6, 7.

This species occurs in all of the material including Recent species. A monographic revision of the genus *Globigerina* will be necessary in order to determine the stratigraphic range of *G. bulloides*. At the present time there are scores of references ranging from the Upper Cretaceous to the Recent and including many diverse forms. Bermudez notes the range of the species from the lower Oligocene to Recent in Cuba (he includes no figures). Hornibrook (personal communication, 9 January 1952) reports that *G. bulloides* in New Zealand ranges from lower Oligocene to Recent. In material from the Mid-Pacific area *G. bulloides* d'Orbigny occurs in upper Paleocene and Eocene sediments.

GLOBIGERINA COMPRESSA Plummer, 1926
Plate 31, figs. 14–15

Globigerina compressa PLUMMER, 1926, Univ. of Texas Bull., no. 2644, p. 135, pl. 8, fig. 11a–c.

This species recently reported as a world-wide index fossil (Grimsdale, 1951) is com-

mon in the upper Paleocene fauna from Hess Guyot.

GLOBIGERINA CRETACEA d'Orbigny, 1840
Plate 31, fig. 12

Globigerina cretacea D'ORBIGNY, 1840, Mem. Soc. Geol. France, ser. 1, vol. 4, p. 34, pl. 3, figs. 12–14.
Globigerina cretacea CUSHMAN, 1931, Tennessee Geol. Bull. 41, p. 58, pl. 10, figs. 6, 7.

This species appears to be distinctive because of its flat spire on the dorsal side and ventrally the four to six inflated almost uniform chambers in the last formed whorl around the large umbilicus into which the chambers each have an aperture. The multiple aperture distinguishes this species from other similar species such as *G. pseudobulloides* Plummer, and *G. infracretacae* Glaessner.

This species has been reported from the Upper Cretaceous to the Recent, but the Cretaceous species of d'Orbigny appears to be extinct. Glaessner reports (1945, p. 206), "The typical large *Globigerina cretacea* d'Orbigny, with umbilical apertures in each of its chambers, makes its first appearance in the Turonian"; (p. 208): "—*Globigerina cretacea*,—disappear(s) suddenly at the boundary between the Senonian and Danian—". Bermudez (1950) records the species in Cuba from the Upper Cretaceous through the Paleocene and questionably to the middle Eocene. *G. cretacea* has a world-wide distribution; it is common in the cores at MP 27 and in the Paleocene indurated *Globigerina* ooze from Hess Guyot.

GLOBIGERINA DIGITATA Brady, 1879

Globigerina digitata BRADY, 1879, Jour. Micr. Sci., vol. 19, p. 72; Report Voy. *Challenger*, Zool., vol. 9, p. 599, pl. 80, figs. 6–10.

This species is rare in the Recent assemblages from the Mid-Pacific Mountains area.

GLOBIGERINA EGGERI Rhumbler, 1900

Globigerina dubia BRADY (not Egger), 1879, Quart. Jour. Micr. Sci., vol. 19, n.s., p. 71; 1884, Report Voy. *Challenger*, Zool., vol. 9, p. 595, pl. 79, figs. 17a–c.
Globigerina eggeri RHUMBLER, 1900, Nordische Plankton, pt. 14, Foraminiferen, p. 19, text figs. 20a–c.
Globigerina eggeri PHLEGER and PARKER, 1951, Mem. Geol. Soc. America no. 46, p. 34, pl. 19, figs. 8, 9.

This species is common in all of the Recent assemblages.

GLOBIGERINA EOCAENA Gümbel, 1868
Plate 31, fig. 25

Globigerina eocaena GÜMBEL, 1868, K. Bayer. Akad. Wiss. München, Math.-Physik. Cl., Abh., München, Deutschland, Bd. 10 (1870), Abt. 2, p. 662, pl. 2, fig. 109a–b.

This species is rare in the indurated *Globigerina* ooze from Hess Guyot.

GLOBIGERINA HEXAGONA Natland, 1938

Globigerina hexagona NATLAND, 1938, Bull. Scripps Inst. Ocean., Tech. Ser., vol. 4, p. 149, pl. 7, figs. 1a–c.

This planktonic species occurs rarely in the modern faunas of the Mid-Pacific area.

GLOBIGERINA INFLATA d'Orbigny, 1839

Globigerina inflata D'ORBIGNY, 1839, in Barker-Webb and Berthelot, Hist. Nat. Iles Canaries, vol. 2, pt. 2, p. 134, pl. 2, figs. 7–9.
Globigerina inflata PHLEGER and PARKER, 1951, Geol. Soc. America Mem. 46, p. 34, pl. 19, figs. 10, 11.

This species is common in all of the Recent assemblages.

GLOBIGERINA LINAPERTA Finlay, 1939
Plate 32, figs. 5, 6

Globigerina linaperta FINLAY, 1939, Trans. Roy. Soc. New Zealand, vol. 69, p. 125, pl. 13, figs. 54–57.

This New Zealand species has been reported from Egypt (Nakkady, 1950) and is common in the Eocene fauna from Horizon Guyot. Hornibrook (personal communication, 9 January 1952) reports that in New Zealand the species ranges from the Teurian to the Kaiatan (possibly Runangan)—Upper Cretaceous (upper Senonian) to upper Eocene. The distribution now established for this form makes it an important world-wide index fossil.

According to its author this species is distinguished by its slight flattening and compression of each chamber and especially by its wide but very low and hardly open aperture with a pronounced rim directed laterally to overhang a previous chamber instead of centrally.

GLOBIGERINA MCKANNAI White, 1928
Plate 32, figs, 21, 26, 30

Globigerina mckannai WHITE, 1928, Jour. Paleontology, vol. 2, p. 194, pl. 27, fig. 16.

A form which appears to fall in this species is common in the Eocene cores from Horizon Guyot. *G. mckannai* was described

by White from the Velasco shale of Mexico and is apparently restricted to that formation in the Tampico Embayment area.

GLOBIGERINA ORBIFORMIS Cole, 1927
Plate 32, fig. 11

Globigerina orbiformis COLE, 1927, Bull. Am. Paleon., vol. 14, no. 51, p. 33, pl. 5, fig. 7.

This species is rare in the Eocene cores from Horizon Guyot. Topotype material from the National Museum was used for comparison.

GLOBIGERINA OUACHITAENSIS Howe and Wallace, 1932
Plate 32, fig. 13

Globigerina ouachitaensis HOWE and WALLACE, 1932, La. Dept. Cons., Geol. Bull. 22, p. 195, pl. 10, figs. 7a–b.

This species occurs in the middle and upper Eocene of the Gulf Coast and adjacent areas. It occurs rarely in the cores at MP 27 and in the Eocene fauna from Horizon Guyot.

GLOBIGERINA OUACHITAENSIS Howe and Wallace var. SENILIS Bandy, 1949
Plate 32, fig. 14

Globigerina ouachitaensis HOWE and WALLACE, 1932, La. Dept. of Cons., Geol. Bull. 22, p. 195, pl. 10, figs. 7a–b.
Globigerina ouachitaensis HOWE and WALLACE var. *senilis* Bandy, 1949, Bull. Am. Paleon., no. 131, p. 121, pl. 22, figs. 5a–c.

This form is rare in the Eocene cores from Horizon Guyot.

GLOBIGERINA PSEUDOBULLOIDES Plummer, 1926
Plate 31, figs. 10–11

Globigerina pseudobulloides PLUMMER, 1926, Univ. of Texas Bull. No. 2644, p. 133, pl. 8, figs. 9a–c.

This species is common in the indurated *Globigerina* ooze from Hess Guyot. This species is close to *G. cretacea* d'Orbigny, but the aperture of the latter is larger and multiple and lacks the flaring lip which is a distinctive feature of *G. pseudobulloides*.

Plummer (1926) notes that this species is common in the Midway of Texas. Glaessner (1937) records the species from the Caucasus with a range from Maestrichtian (?)-Danian, Paleocene-lower Eocene (?). Nuttall (1930) records the species from the lower Eocene of Mexico.

GLOBIGERINA QUINQUELOBA Natland, 1938

Globigerina quinqueloba NATLAND, 1938, Bull. Scripps Inst. Ocean., Tech. Ser., vol. 4, p. 149, pl. 6, figs. 7a–c.

This species, formerly known only from the Pacific, has now been found in the Atlantic (personal communication, F. L. Parker). It is rare in the Mid-Pacific modern faunas.

GLOBIGERINA ROTUNDATA d'Orbigny var. JACKSONENSIS Bandy, 1949
Plate 32, fig. 15

Globigerina rotundata jacksonensis BANDY, 1949, Bull. Am. Paleon., vol. 32, no. 131, p. 121, pl. 23, figs. 6a–c.

This form is rare in the Eocene cores from Horizon Guyot.

GLOBIGERINA SUBCRETACEA Lomnicki, 1901
Plate 30, fig. 32

Globigerina subcretacea LOMNICKI, 1901, Otwornice Miocenu Pokucia, Akad. Umiejetnosci w Krakowie, Czes. II, p. 41–65; fig. Brady, Report *Challenger* Exped., vol. 9, pl. 82, fig. 10.
Globigerina subcretacea CHAPMAN, 1902, Jour. Linn. Soc., Zool., vol. 28, p. 410, pl. 36, figs. 16a–b (p. 404-list).

This species is distinguished from *G. eggeri* by the very flat spire on the dorsal side. It is rare in the cores from MP 27. *G. subcretacea* has been reported from the Pliocene and Pleistocene of California. It is a modern form in planktonic assemblages.

GLOBIGERINA TRILOCULINOIDES Plummer, 1926
Plate 30, fig. 19; plate 31, fig. 13

Globigerina triloculinoides PLUMMER, 1926, Univ. of Texas Bull. No. 2644, p. 134, pl. 8, figs. 10 a–c.

This species is extremely widespread in sediments from the Danian to the lower Eocene; it is common in the cores from MP 27, the indurated *Globigerina* ooze from Hess Guyot and from pockets and interstices in rocks from Horizon, Hess and Cape Johnson Guyots.

GLOBIGERINA VENEZUELANA Hedberg, 1937
Plate 30, fig. 31

Globigerina venezuelana HEDBERG, 1937, Jour. Paleontology, vol. 11, p. 681, pl. 92, fig. 7.

Type description: Large, nearly spherical; chambers inflated; the last three making up the bulk of the test; the early chambers form a compact spiral; wall coarsely cancellate;

aperture in a deep triangular depression between the last chambers; rare supplementary apertures are also present in some specimens. Diameter of holotype: 0.56 mm.

As figured in the original descriptions, *G. conglomerata* and *G. ouachitaensis* are not as globose as *G. venezuelana* and both appear to have four chambers of almost equal size making up the last formed whorl.

The geologic range of *G. venezuelana* is recorded from upper Eocene (Bermudez, 1950) to the middle Miocene. This species is rare in the mixed Upper Cretaceous to Recent fauna from MP 27-2.

Genus GLOBIGERINOIDES Cushman, 1927

GLOBIGERINOIDES CONGLOBATA (Brady),* 1879

Globigerina conglobata BRADY, 1879, Quart. Jour. Micr. Sci., vol. 19, p. 72; Report Voy. *Challenger*, Zool., vol. 9, p. 603, pl. 80, figs. 1–5; pl. 82, fig. 5.

Globigerinoides conglobata PHLEGER and PARKER, 1951, Geol. Soc. America Mem. 46, p. 35, pl. 19, fig. 15.

This species is common in the Recent assemblages from the Mid-Pacific Mountains area.

GLOBIGERINOIDES MEXICANA (Cushman), 1925

Plate 32, fig. 27

Globigerina mexicana CUSHMAN, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, p. 6, pl. 1, fig. 8.

This species is rare in the Eocene cores from Horizon Guyot and in the mixed Upper Cretaceous to Recent fauna from MP 27.

GLOBIGERINOIDES NUTTALLI Hamilton, n. sp.

Plate 32, figs. 22–24

Globigerina sp. NUTTALL, 1930, Jour. Paleontology, vol. 4, p. 290, pl. 24, figs. 12–15.

Description.—Test trochoid, calcareous, perforate, globose, almost as wide as high; chambers increasing rapidly in size; well-defined chambers typically 9–10 and arranged in three distinct whorls; the chambers of the first two four-chambered whorls globose; last chambers usually somewhat flattened and vary in size and shape; periphery distinctly lobulate between the globose chambers; wall structure, the typical hexagonal pore structure of the glo-

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EXPLANATION OF PLATE 31

Upper Paleocene fauna from Hess Guyot; from indurated *Globigerina* ooze at 915 fathoms.

FIGS. *1–4*—*Gümbelina ultimatumida* White. Four specimens; *1*, front view, of two large-chambered form, ×49; *2*, side view, ×49; *3*, front view of four large-chambered form, ×54; *4*, apertural view, ×54. (p. 235)

5, 6—*Gümbelina glabrans* Cushman. Two specimens; *5*, front view; *6*, side view; ×52. (p. 234)

7, 8—*Gümbelina* aff. *G. midwayensis* Cushman. Two specimens; *7*, front view; *8*, view of opposite side; ×52. (p. 234)

9—*Gümbelina globulosa* (Ehrenberg). Front view; ×52. (p. 234)

10, 11—*Globigerina pseudobulloides* Plummer. Two specimens; *10*, dorsal view; *11*, ventral view; ×52. (p. 223)

12—*Globigerina cretacea* d'Orbigny. Ventral view; ×52. (p. 222)

13—*Globigerina triloculinoides* Plummer. Ventral view; ×46. (p. 223)

14, 15—*Globigerina compressa* Plummer. Two specimens; *14*, dorsal view; *15*, ventral view; ×51. (p. 221)

16—*Globigerinella pseudovoluta* Bandy; ×54. (p. 226)

17, 18—*Globorotalia crassata* (Cushman). Two specimens; *17*, ventral view; *18*, dorsal view; ×54. (p. 229)

19, 20—*Globorotalia* aff. *G. angulata* (White). Two specimens; *19*, ventral view, ×62; *20*, dorsal view, ×47. (p. 229)

21—*Globorotalia* aff. *G. inconspicua* Howe. Ventral view; ×53. (p. 230)

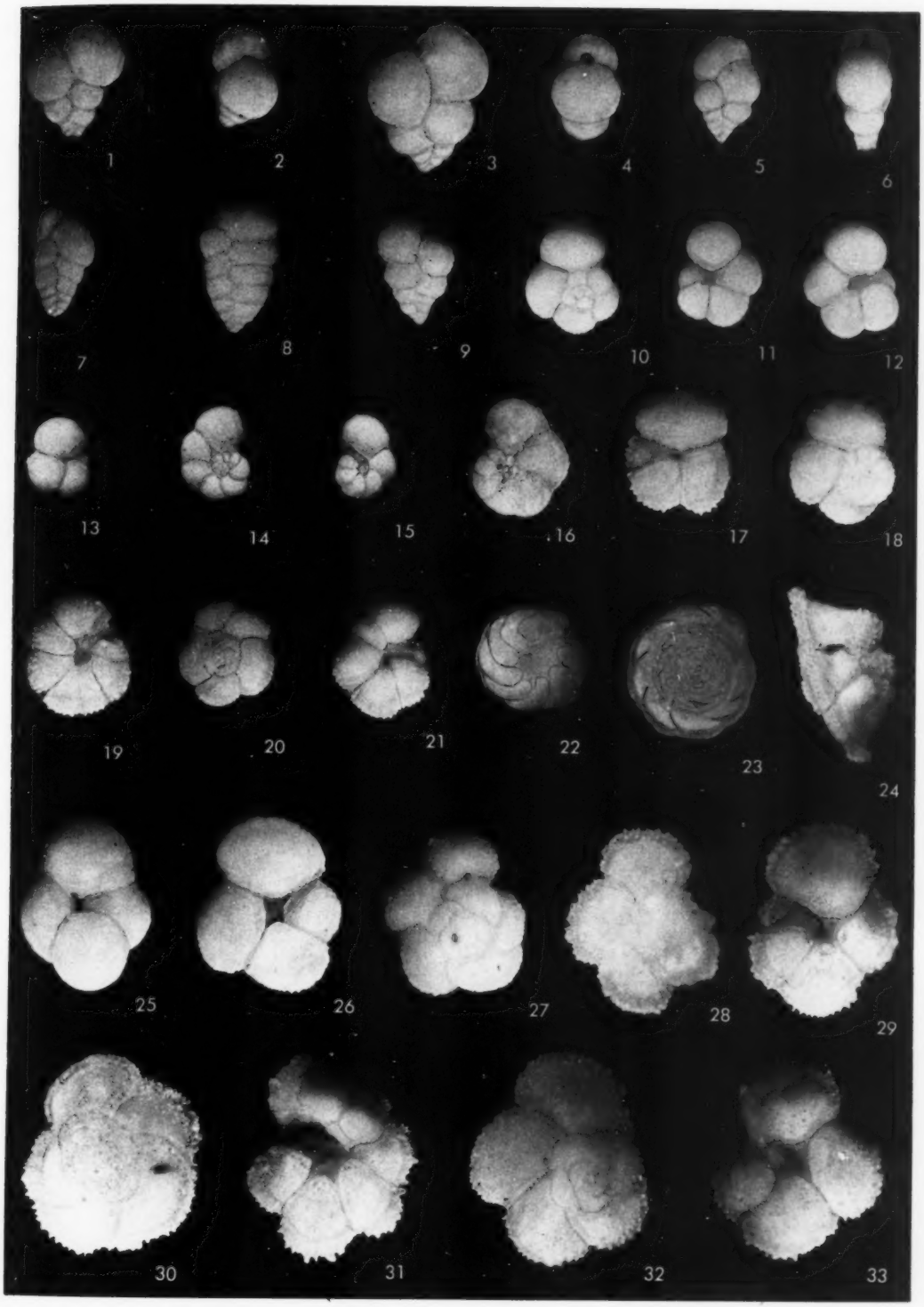
22, 23—*Eponides trümpyi* Nuttall. Two specimens; *22*, ventral view; *23*, dorsal view; ×53. (p. 235)

24, 28–31—*Globorotalia velascoensis* (Cushman). Five specimens; *24*, side view of five-chambered specimen; *28*, dorsal view; *29*, ventral view; *30*, dorsal view of six-chambered form (note beaded sutures); *31*, ventral view of six-chambered form; ×47. (p. 231)

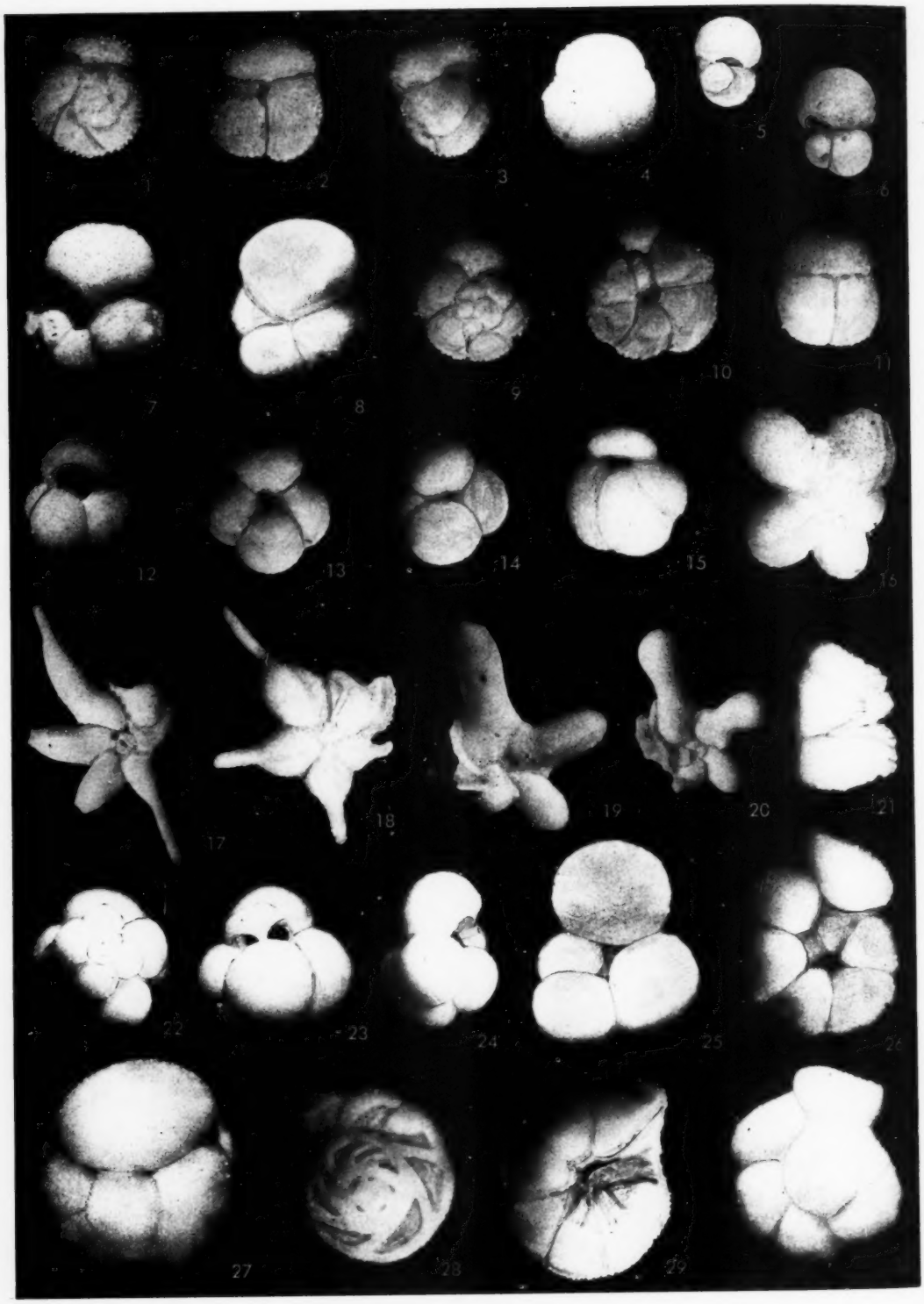
25—*Globigerina eocaena* Gümbel. Ventral view; ×53. (p. 222)

26, 27—*Globigerina bulloides* d'Orbigny. Two specimens; *26*, ventral view, ×57; *27*, ventral view, ×54. (p. 221)

32, 33—*Globorotalia velascoensis* (Cushman) var. *acuta* (Toulmin) Grimsdale. Two specimens; *32*, dorsal view (note lack of beaded sutures); *33*, ventral view; ×56. (p. 231)



Hamilton, Foraminifera from Pacific seamounts



Hamilton, Foraminifera from Pacific seamounts

bigerinids; multiple apertures along the suture lines varying in number from one in the last chamber to two in the last chamber and one or two others into earlier chambers; apertures vary in shape from low arched openings into the last chamber to round openings into earlier chambers; some apertures have a poorly defined lip. The holotype is selected as the specimen illustrated in plate 32, fig. 23.

Dimensions.—Holotype: height 0.48 mm., width 0.45 mm. The holotype is about average in size. The variation in size from this average is about 0.10 mm.

Holotype.—Plate 32, fig. 23. Holotype to be deposited in the U. S. National Museum, Washington, D. C.

Type Locality.—Flat topped seamount (Horizon Guyot) at the southwest end of the volcanic ridge indicated on the U. S. Navy H. O. Chart No. 0528 at about 19°40′N. Lat. and 168°32′W. Long. This species is common in the unindurated *Globigerina* ooze taken in two Phleger cores at a depth of about 940 fathoms on the flat top of the seamount just above the break in slope between the flat top and the upper side slopes. Preservation is excellent.

Geologic age.—Lower Eocene.

Discussion.—This species was identified by the writer as *Globigerina* sp. Nuttall (1930). Nuttall's (1930) plesiotypes were obtained from the U. S. National Museum and it could be seen by comparison that these Mexican specimens had chambers which were more flattened than the Mid-Pacific specimens, but were still probably within a range of variation. The writer then sent a slide of identified specimens (including *Globigerina* sp.) to W. L. F. Nuttall in London with a request for his opinion. C. D. Ovey, to whom Nuttall referred the request, replied (personal communication, 21 March, 1952): "Your *Globigerina* sp. is identical with a *Globigerina* sp. (Registered No. P 39535) [British Museum (Natural History)] we have from the Aragon formation which, judging from Nuttall's account and figures, is the same as his *G.* sp."

Globigerinoides nuttalli occurs in a planktonic fauna which is very similar to the planktonic fauna of the Aragon formation of the Tampico Embayment region of Mexico (uppermost lower Eocene). *G. nuttalli* is named after Dr. W. L. F. Nuttall who first illustrated it from the Aragon formation but did not name it.

EXPLANATION OF PLATE 32

Eocene fauna from Horizon Guyot; unconsolidated *Globigerina* ooze from cores.

FIGS. *1–3—Globorotalia crassata* (Cushman). Three specimens; *1*, dorsal view; *2*, ventral view; *3*, side view; ×55. (p. 229)

4—Globorotalia crassata densa (Cushman). Ventral view; ×52. (p. 230)

5, 6—Globigerina linaperta Finlay. Two specimens; *5*, side view; *6*, ventral view; ×35. (p. 222)

7—Globorotalia wilcoxensis Cushman and Ponton. Ventral view of specimen from MP 27; ×52 (p. 231)

8—Globorotalia centralis Cushman and Bermudez. Ventral view; ×52. (p. 229)

9, 10—Globorotalia aff. *G. angulata* (White). Two specimens; *9*, dorsal view, ×51; *10*, ventral view, ×55. (p. 229)

11—Globigerina orbiformis Cole. Ventral view; ×52. (p. 223)

12—Globigerina apertura Cushman. Ventral view; ×54. (p. 220)

13—Globigerina ouachitaensis Howe and Wallace. Ventral view; ×54. (p. 223)

14—Globigerina ouachitaensis Howe and Wallace var. *senilis* Bandy. Ventral view; ×52 (p. 223)

15—Globigerina rotundata d'Orbigny var. *jacksonensis* Bandy. Ventral view; ×54. (p. 223)

16—Hastigerinella eocanica Nuttall; ×48. (p. 227)

17, 18—Hantkenina mexicana Cushman var. *aragonensis* Nuttall. Two specimens; *17*, form with extremely long chambers; ×33; *18*, ×48. (p. 229)

19, 20—Hastigerinella eocanica aragonensis Nuttall. *20*, variation with bulbous-ended chambers; ×33. (p. 227)

21, 26, 30—Globigerina mckannai White. Three specimens; *21*, side view; *26*, ventral view; *30*, dorsal view; ×53. (p. 222)

22–24—Globigerinoides nuttalli Hamilton, n. sp. Three specimens; *22*, dorsal view; *23*, side view of holotype; *24*, side view; ×52. (p. 224)

25—Globigerina bulloides d'Orbigny. Ventral view; ×53. (p. 221)

27—Globigerinoides mexicana (Cushman). Side view, ×52. (p. 224)

28, 29—Globorotalia aragonensis Nuttall. Two specimens; *28*, dorsal view; *29*, ventral view; ×47. (p. 229)

GLOBIGERINOIDES RUBRA (d'Orbigny), 1839

Globigerina rubra D'ORBIGNY, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba p. 82, pl. 4, figs. 12–14.

This is the most abundant species in the Recent planktonic assemblages from the Mid-Pacific Mountains area.

GLOBIGERINOIDES SACCULIFERA (Brady), 1877

Globigerina sacculifera BRADY, 1877, Geol. Mag., vol. 4, p. 535. 1884, Report Voy. *Challenger*, Zool., vol. 9, p. 604, pl. 80, figs. 11–17; pl. 82, fig. 4.

This species is common in the Recent assemblages from the Mid-Pacific Mountains area.

Genus GLOBIGERINITA Bronnimann, 1951

GLOBIGERINITA GLUTINATA (Egger), 1893

Globigerina glutinata EGGER, 1893, Abhandl. k. bay. Akad. Wiss. Munchen, Cl. II, vol. 18, p. 371, pl. 13, figs. 19–21.

Globigerina glutinata RHUMBLER, 1911, Ergeb. Plankton-Exped. Humboldt Stift., vol. 3, p. 148, pl. 29, figs. 14–26; pl. 33, fig. 20; pl. 34, fig. 1.

Globigerina glutinata Egger has been placed in Bronnimann's genus by Miss Frances L. Parker of Scripps Institution in a manuscript based on studies of North Atlantic deep-sea cores (personal communication, September, 1951). The species is rare in the modern faunas of the Mid-Pacific area.

Genus GLOBIGERINELLA Cushman, 1927

GLOBIGERINELLA AEQUILATERALIS (Brady), 1879

Globigerina aequilateralis BRADY, 1879, Quart. Jour. Micro. Sci., vol. 19, p. 71; 1884, Report Voy. *Challenger*, Zool., vol. 9, p. 605, pl. 80, figs. 18–21.

Globigerinella aequilateralis PHLEGER and PARKER, 1951, Geol. Soc. America Mem. 46, p. 35, pl. 19, fig. 14.

This species occurs rarely in the Recent assemblages from the Mid-Pacific Mountains area.

GLOBIGERINELLA ASPERA (Ehrenberg), 1854
Plate 30, fig. 5

Rotalia aspera EHRENBERG, 1854, Mikrogeologie, Leipzig, Taf. 27, figs. 57–58; Taf. 28, figs. 42, 42a. For complete synonymy see Bandy (1951).

This species is rare in the mixed Upper Cretaceous to Recent fauna from MP 27-2.

GLOBIGERINELLA PSEUDOVOLUTA Bandy, 1949
Plate 31, fig. 16

Globigerinella pseudovoluta BANDY, 1949, Bull. Am. Paleon., vol. 32, no. 131, p. 23, pl. 24, figs. 4a–b.

This species is common in the Eocene cores from Horizon Guyot and occurs rarely in the upper Paleocene fauna from Hess Guyot. Forms identified by the writer were sent to Dr. O. L. Bandy who examined them and affirmed that they were *G. pseudovoluta* Bandy. Dr. Bandy states: "Even though poorly preserved, the coarsely perforate or reticulate wall structure is discernible."

The problem of the correct taxonomic positions of *G. pseudovoluta* Bandy, *Nonion micrus* Cole, and *Nonion danvillensis* Howe and Wallace is an important one because these forms are world-wide in distribution and are important index fossils. Glaessner (1937) placed *Nonion micrus* Cole in the genus *Globigerinella* and placed *N. danvillensis* in synonymy with it. Grimsdale (1951) followed Glaessner and added *G. pseudovoluta* to the synonymy. Dr. Cole kindly sent a topotype slide of *N. micrus* to Dr. Bandy and after viewing it both Dr. Bandy and the writer believe that *N. micrus* is not the same species as *G. pseudovoluta* Bandy. Dr. Bandy (personal communication, 29 January 1952) stated: "The Cole slide has specimens that are certainly *Nonion*. Of course the perforations are conspicuous but they are fine to medium in size and they do not produce the coarsely reticulate wall structure of the globigerinoids." Dr. Bandy (personal communication, 3 January 1952) stated that in his Little Stave Creek studies (Bandy, 1949) he found that *N. danvillensis* could be differentiated from *N. micrus* by the papillate umbilical region of *N. danvillensis* (which is illustrated in the holotype figure). It would appear then that all three species are distinct. A complicating factor in the problem is that Dr. M. N. Bramlette of Scripps Institution crushed an *N. micrus* collected from the Guayabal formation of Mexico and examined it under the petrographic microscope and found that it had

the radial wall structure of the globigerinids rather than the granular structure of *Nonion*. This problem deserves study by someone with a large suite of *N. micrus* Cole. At the present time the writer believes that *G. pseudovoluta* Bandy is a distinct species with world-wide distribution. The figure of *N. micrus* Cole of Glaessner (1937, Taf. 1, fig. 4 a–b) from the Eocene of the Caucasus appears to the writer to be a *G. pseudovoluta* Bandy, but lacking type material the writer is not placing it in synonymy.

GLOBIGERINELLA VOLUTA (White), 1928
Plate 30, fig. 6

Globigerina voluta WHITE, 1928, Jour. Paleontology, vol. 2, p. 197, pl. 28, fig. 5.

A single specimen of this species was found in the mixed Upper Cretaceous to Recent fauna from MP 27-2. White reports it from the Velasco and Mendez formations of the Tampico Embayment area of Mexico.

Genus RUGOGLOBIGERINA Bronnimann, 1952

RUGOGLOBIGERINA RUGOSA RUGOSA (Plummer) Bronnimann, 1952
Plate 30, figs. 1–3

Globigerina rugosa PLUMMER, 1926, Univ. of Texas Bull. 2644, p. 38, pl. 2, figs. 10a–d.
Rugoglobigerina rugosa rugosa (Plummer) BRONNIMANN, 1952, Bull. Am. Paleon., vol. 34, no. 140, p. 28, text figs. 11–13.

Bronnimann (1952) has revised the group of Cretaceous rugose globigerinids into which this species falls and has erected the new genus *Rugoglobigerina* with Plummer's species as the genotype. This species is very close to the genus *Globotruncana* and appears to be an intermediate form between that genus and *Globigerina*. Plummer (1926) notes that the umbilical features of *Globigerina rugosa* are precisely those of *Globotruncana rosetta* (Carsey). With two peripheral keels *Rugoglobigerina rugosa* would become *Globotruncana globigerinoides* Brotzen. *R. rugosa rugosa* is common in the cores at MP 27; it has been recorded from the Navarro of Texas, the Ripley formation of Alabama, and from the Cretaceous of Trinidad.

Genus HASTIGERINELLA Cushman, 1927
HASTIGERINELLA EOCANICA Nuttall, 1928
Plate 32, fig. 16

Hastigerinella eocanica NUTTALL, 1928, Jour. Paleontology, vol. 2, p. 376, pl. 50, figs. 9–11.

This species is rare in the Eocene cores from Horizon Guyot. *H. eocanica* is established as a good index fossil with a world-wide distribution. It is reported from the Gulf of Mexico and Caribbean area, the Middle East and from the Middle Pacific; its geologic range is lower Eocene to lower Oligocene.

H. digitata (Rhumbler) differs from *H. eocanica* in having spines on the ends of the chambers; *H. eocanica aragonensis* Nuttall has more elongate chambers and *H. jarvisi* Cushman has chambers more elongate than *H. eocanica aragonensis* and with spines on the ends of the chambers.

HASTIGERINELLA EOCANICA Nuttall var. ARAGONENSIS Nuttall, 1930
Plate 32, figs. 19–20

Hastigerinella eocanica NUTTALL, 1928, Jour. Paleontology, vol. 2, p. 376, pl. 50, figs. 9–11.
Hastigerinella eocanica Nuttall var. *aragonensis* NUTTALL, 1930, Jour. Paleontology, vol. 4, p. 290, pl. 24, figs. 16–17.

This variety differs from the species in having more elongate chambers. It occurs rarely in the Eocene cores from Horizon Guyot. Figure 17 of the type reference for this variety indicates that Nuttall included forms whose chambers were rounded and slightly bulbous at the ends. The form illustrated in this paper (plate 32, fig. 20) has chambers which become more bulbous at the ends as they grow larger. The writer considers this form as a variation of *H. eocanica aragonensis*. At the present time no useful stratigraphic purpose would be achieved by assigning a new varietal name.

Genus ORBULINA d'Orbigny, 1839
ORBULINA UNIVERSA d'Orbigny, 1839

Orbulina universa D'ORBIGNY, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, p. 3, pl. 1, fig. 1.

This species is common in the Recent assemblages from the Mid-Pacific Mountains area.

The lower range of *O. universa* as a world wide index of the Tertiary is of interest

(LeRoy, 1948). It is recorded from the middle Oligocene to the Recent in the Caribbean area. Grimsdale (1951) thinks that the species is not older than the Miocene in the Gulf Coast and Caribbean area and in the Middle East. Hornibrook (personal communication, 9 January 1952) notes that the range of *O. universa* in New Zealand is from lower Miocene to Recent. Bronnimann (1951) summarizes the first appearance of the genus *Orbulina* in the Caribbean region and concludes that its first appearance is definitely in the Oligocene, but not at the same time in different localities in the Caribbean region. There appears to be valid evidence that *O. universa* first appeared in the sediments of middle to upper Oligocene age.

Genus PULLENIATINA Cushman, 1927
PULLENIATINA OBLIQUILOCULATA (Parker and Jones), 1865

Pullenia obliquiloculata PARKER and JONES, 1865, Phil. Trans., vol. 155, p. 368, pl. 19, figs. 4a–b.

Pulleniatina obliquiloculata PHLEGER and PARKER, 1951, Geol. Soc. America Mem. 46, p. 35, pl. 19. figs. 19, 20.

This species is rare in the Recent assemblages from the Mid-Pacific Mountains area.

Genus SPHAEROIDINELLA Cushman, 1927
SPHAEROIDINELLA DEHISCENS (Parker and Jones), 1865

Sphaeroidina dehiscens PARKER and JONES, 1865, Phil. Trans., vol. 155, p. 369, pl. 19, figs. 5a–c.

Sphaeroidinella dehiscens SCHOTT, 1935, Wiss. Ergeb. deutsch. Atlantisch. Exped. Forsch. Vermess. "Meteor" 1925–1927, vol. 3, pt. 3, Sect. B, p. 59.

This species is common in the Recent assemblages from the Mid-Pacific Mountains area.

SPHAEROIDINELLA MULTILOBA LeRoy, 1944
Plate 30, fig. 26

Sphaeroidinella multiloba LEROY, 1944, Colorado School Mines Quart. 39, no. 3, p. 91, pl. 4, figs. 7–9.

Forms which seem to fall into this species are rare in the mixed Upper Cretaceous to Recent fauna from MP 27-2. This form is probably a variation of *S. rutschi* Cushman and Renz. Miss Frances L. Parker has studied material from Atlantic deep-sea cores which contain lobate forms varying from *S. rutschi* and very similar, if not the same as *S. multiloba*. A large suite of *S. rutschi*, *S. multiloba* and *S. seminulina* might well reveal that the three species are variations of one species. Fortunately the three species have about the same geologic range.

SPHAEROIDINELLA RUTSCHI Cushman and Renz, 1941
Plate 30, figs. 24–25

Sphaeroidinella rutschi CUSHMAN and RENZ, 1941, Cushman Lab. Foram. Res., Contr., vol. 17, p. 25, pl. 4, figs. 5a–c.

As noted by Phleger and Parker (unpublished manuscript) this species is closely related to, if not the same as, *S. seminulina* Schwager. The writer examined topotype material of specimens of *S. rutschi* and *S. seminulina* sent to Miss Frances L. Parker from the U. S. National Museum. In Miss Parker's opinion and that of the writer, the two species (in the material at hand) are the same with the possible exception that the wall of *S. seminulina* appeared to be thinner, almost translucent, and with a round pore structure which appeared as white dots, whereas *S. rutschi* had the typical hexagonal pore structure of the Globigerinidae, and a thicker, whiter wall. This problem should be studied by someone with a large number of topotype specimens of both species. Fortunately the two species are reported to have about the same geologic range: *S. seminulina* from the upper Oligocene to the lower Pliocene and *S. rutschi* from the middle Oligocene to the middle Miocene.

SPHAEROIDINELLA SEMINULINA (Schwager), 1866
Plate 30, figs. 27–28

Globigerina seminulina SCHWAGER, 1866, Novara. Exped., Geol. Theil, vol. 2, p. 256, pl. 7, fig. 112.

Sphaeroidinella seminulina BERMUDEZ, 1949, Cushman Lab. Foram. Res., Sp. Publ. 25, p. 283, pl. 21, fig. 59.

This species differs from *S. dehiscens* in its smaller size and by the lack of an aperture on the dorsal side. *S. seminulina* occurs rarely in the cores from MP 27.

For further remarks see note under *S. rutschi*.

Genus CANDEINA d'Orbigny

CANDEINA NITIDA d'Orbigny, 1839

Candeina nitida D'ORBIGNY, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, p. 108, pl. 2, figs. 27, 28.
Candeina nitida BRADY, 1884, Report *Challenger*, Zool., vol. 9, p. 622, pl. 82, figs. 13–20.

This species is rare in the Recent assemblages from the Mid-Pacific Mountains area.

Family HANTKENINIDAE

Genus HANTKENINA Cushman, 1924

HANTKENINA ALABAMENSIS Cushman, 1924

Plate 30, fig. 20

Hantkenina alabamensis CUSHMAN, 1924, Proc. U. S. Nat. Mus., vol. 66, art. 30, p. 3, pl. 1, figs. 1–6; pl. 2, fig. 5.

One broken specimen of this species was found in the mixed Upper Cretaceous to Recent fauna from MP 27-2.

HANTKENINA MEXICANA Cushman var. ARAGONENSIS Nuttall, 1930

Plate 32, figs. 17, 18

Hantkenina mexicana CUSHMAN, 1924, Proc. U. S. Nat. Mus., vol. 66, art. 30, p. 3, pl. 2, fig 2.
Hantkenina mexicana Cushman var. *aragonensis* NUTTALL, 1930, Jour. Paleontology, vol. 4, p. 284, pl. 24, figs. 1–3.

This variety differs from the type in having larger more inflated chambers which always taper more gradually into the terminal spines. Thalmann (1942b) elevated this variety to specific rank, but Bronnimann (1950) stated that: "In the present material it was difficult to distinguish consistently between them (*H. mexicana* and *H. mexicana aragonensis*-writer's note) and therefore it is considered that the two forms are the extreme variants of a single species, connected by transitional forms."

Family GLOBOROTALIIDAE

Genus GLOBOROTALIA Cushman, 1927

GLOBOROTALIA aff. G. ANGULATA (White), 1928

Plate 31, figs. 19, 20; plate 32, figs. 9, 10

Globigerina angulata WHITE, 1928, Jour. Paleontology, vol. 2, p. 191, pl. 27, fig. 13a–c.
Globorotalia angulata (White) GLAESSNER, 1937, Publ. Paleon. Lab. Moscow Univ., Problems in Paleontology, II–III, p. 383, pl. 4, figs. 35a–c; 36a–c; 37a–c.

Forms which are close to *G. angulata* White, but with a more rounded periphery, are rare in the upper Paleocene fauna from Hess Guyot.

GLOBOROTALIA ARAGONENSIS Nuttall, 1930

Plate 32, figs. 28, 29

Globorotalia aragonensis NUTTALL, 1930, Jour. Paleontology, vol. 4, p. 288, pl. 24, figs. 6–8, 10, 11.

This species first reported from the Aragon formation of Mexico is a world-wide index fossil for the lower and middle Eocene. It is reported from the Middle East, the Gulf Coast and Caribbean area and now from the Mid-Pacific. *G. aragonensis* is abundant in cores from the top of Horizon Guyot, is common in the indurated *Globigerina* ooze boulder from Guyot 19171, and the cores at MP 27.

GLOBOROTALIA CENTRALIS Cushman and Bermudez, 1937

Plate 32, fig. 8

Globorotalia centralis CUSHMAN and BERMUDEZ, 1937, Contr. Cushman Lab. Foram. Res., vol. 13, p. 26, pl. 2, figs. 62–65.

This form is common in the Eocene cores from Horizon Guyot.

GLOBOROTALIA CRASSATA (Cushman), 1925

Plate 31, figs. 17, 18; plate 32, figs. 1–3

Pulvinulina crassata CUSHMAN, 1925, Bull., Am. Assoc. Pet. Geol., vol. 9, p. 300, pl. 7, fig. 4.
Globorotalia crassata COLE, 1927, Bull. Amer. Paleont., vol. 14, no. 51, p. 34, pl. 1, figs. 7–8.
Globorotalia crassata (CUSHMAN), 1939, Contr. Cushman Lab. Foram. Res., vol. 15, p. 74, pl. 12, fig. 19.

Plesiotype material of the last named citation above was obtained from the National Museum and compared with the material from the Mid-Pacific area. This species is common in the mixed Upper Cretaceous to Recent fauna from MP 27-2 and occurs in the upper Paleocene fauna from Hess Guyot, and is abundant in the Eocene fauna from the cores from Horizon Guyot. It also occurs in the mixed faunas from all five guyots as well as in the Eocene fauna of Guyot 19171.

GLOBOROTALIA CRASSATA (Cushman) var. AEQUA Cushman and Renz, 1942
Plate 30, figs. 21, 22

Pulvinulina crassata CUSHMAN, 1925, Bull., Am. Assoc. Pet. Geol., vol. 9, p. 300, pl. 7, fig. 4.
Globorotalia crassata aequa CUSHMAN and RENZ, 1942, Contr. Cushman Lab. Foram. Res., vol. 18, p. 12, pl. 3, fig. 3.

The variety differs from the species in the much smoother surface, and in that the chambers, especially the later ones, are broader and more arcuate. The variety differs from *G. wilcoxensis* in that the periphery is bluntly angular and unkeeled, and the aperture is elongate.

This variety occurs rarely in the cores from MP 27. It is apparently confined to the Paleocene.

GLOBOROTALIA CRASSATA DENSA (Cushman), 1939
Plate 32, fig. 4

Pulvinulina crassata densa CUSHMAN, 1925, Bull., Am. Assoc. Pet. Geol., vol. 9, p. 301, no figure.
Globorotalia crassata densa (CUSHMAN), 1939, Contr. Cushman Lab. Foram. Res., vol. 15, p. 74, pl. 12, fig. 20.

Plesiotype material of the last named citation was obtained from the National Museum and compared with the forms from the Mid-Pacific area. This variety is common in the Eocene fauna from Horizon Guyot and in the mixed fauna of MP 27-2.

GLOBOROTALIA HIRSUTA (d'Orbigny), 1839

Rotalina hirsuta D'ORBIGNY, 1839, in Barker-Webb and Berthelot, Hist. Nat. Iles Canaries, vol. 2, pt. 2, Foraminiferes, p. 131, pl. 1, figs. 37–39.
Pulvinulina canariensis BRADY (not d'Orbigny), 1884, Report Voy. *Challenger*, Zool., vol. 9, p. 692, pl. 103, figs. 8–10.
Globorotalia hirsuta CUSHMAN, 1931, Bull. 104, U. S. Nat. Mus., pt. 8, p. 99, pl. 17, figs. 6a–c.

This species occurs rarely in the modern faunas of the Mid-Pacific area.

GLOBOROTALIA aff. G. INCONSPICUA Howe, 1939
Plate 31, fig. 21

Globorotalia inconspicua HOWE, 1939, La. Dept. of Cons. Geol. Bull. 14, p. 85, pl. 12, fig. 20–22.

Forms close to *G. inconspicua* Howe, but with a more rounded periphery, are rare in in the upper Paleocene fauna from Hess Guyot and common in the Eocene cores from Horizon Guyot.

GLOBOROTALIA MENARDII (d'Orbigny), 1826

Rotalia menardii D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 273, no. 26; Modeles no. 10.
Pulvinulina menardii BRADY, 1884, Report Voy. *Challenger*, Zool., vol. 9, p. 690, pl. 103, figs. 1,2.
Globorotalia menardii CUSHMAN, 1931, Bull. U. S. Nat. Mus. no. 104, pt. 8, p. 91, pl. 17, figs. 1a–c.
Globorotalia menardii PHLEGER and PARKER, 1951, Geol. Soc. America Mem. no. 46, p. 36, pl. 20, figs. 1, 2.

This species is common to rare in all Recent assemblages from the Mid-Pacific Mountain area. It occurs widely in sediments from the lower Miocene to the Recent. Galloway and Heminway (1941) record *G. menardii* from the lower Oligocene of Porto Rico.

GLOBOROTALIA PUNCTULATA (d'Orbigny), 1826

Globigerina punctulata D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 277, no. 8.
Globorotalia punctulata PHLEGER and PARKER, 1951, Geol. Soc. America Mem. 46, pl. 20, figs. 3–7.

This species is rare in the Recent assemblages of the Mid-Pacific area.

GLOBOROTALIA SCITULA (Brady), 1882

Pulvinulina scitula BRADY, 1882, Proc. Roy. Soc. Edinburgh, vol. 11, p. 716; BALKWILL and MILLET, Jour. Micro., vol. 3, p. 85, pl. 4, fig. 12, 1884.
Globorotalia scitula PHLEGER and PARKER, 1951, Geol. Soc. America Mem. 46, p. 36, pl. 20, figs. 8, 9.

This species is rare in the Recent assemblages from the Mid-Pacific area.

GLOBOROTALIA TRUNCATULINOIDES (d'Orbigny), 1839

Rotalina truncatulinoides D'ORBIGNY, 1839, in Barker-Webb and Berthelot, Hist. Nat. Iles Canaries, vol. 2, pt. 2, p. 132, pl. 2, figs. 25–27.
Globorotalia truncatulinoides PHLEGER and PARKER, 1951, Geol. Soc. America Mem. 46, p. 36, pl. 20, figs. 10–13.

This species is common in the Recent assemblages from the Mid-Pacific Mountains area. Grimsdale (1951) records the species from the upper Miocene to Recent in the Gulf of Mexico and Caribbean areas.

GLOBOROTALIA TUMIDA (Brady), 1877

Pulvinulina menardii d'Orbigny var. *tumida* BRADY, 1877, Geol. Mag., vol. 4, p. 294.
Pulvinulina tumida BRADY, 1884, Report *Challenger* Zool., vol. 9, p. 692, pl. 103, figs. 4–6.

Globorotalia tumida PHLEGER and PARKER, 1951, Geol. Soc. America Mem. 46, p. 36, pl. 20, figs. 14, 15.

This species is common in the Recent assemblages from the Mid-Pacific Mountains area.

GLOBOROTALIA VELASCOENSIS (Cushman), 1925
Plate 30, figs. 16–18, 23; plate 31, figs. 24, 28–31

Pulvinulina velascoensis CUSHMAN, 1925, Cushman Lab. Foram. Res., Contr., vol. 1, p. 19, pl. 3, figs. 5a–c.
Globorotalia velascoensis (Cushman) CUSHMAN, 1927, Jour. Paleontology, vol. 1, pl. 27, figs. 7–9.
Globorotalia velascoensis WHITE, 1928, Jour. Paleontology, vol. 2, p. 281, pl. 38, figs. 2a–c.
Globorotalia aragonensis Nuttall var. *caucasica* GLAESSNER, 1937, Publ. Paleon. Lab. Moscow Univ., Studies in Micropaleontology, vol. 1, fasc. 1, p. 31, figs. 6a–c.

This species is an outstanding index fossil with a world-wide distribution. It is the most abundant species in the Velasco shale of the Tampico Embayment region of Mexico, and has been noted from Cuba, Trinidad, Florida, Egypt and the Middle East. The specimens from the Mid-Pacific area are extremely well preserved and abundant. It is the dominant species in the indurated *Globigerina* ooze from Hess Guyot and is found on Horizon and Cape Johnson Guyots and from the cores at MP 27.

In view of its importance as an index fossil the geologic range of *G. velascoensis* assumes some importance. Grimsdale (1947 and 1951) records the form as upper Paleocene to lower Eocene in the Gulf of Mexico and Caribbean areas and from the upper Paleocene to middle Eocene in the Middle East. He (1951) specifically states that the form is not found in the lower part of the Velasco shale in Mexico. Cushman (1927) states that *G. velascoensis* is common in the lower and middle Velasco. Bermudez (1950) records the form from the Upper Cretaceous Habana formation of Cuba. Cushman and Bermudez (1949) also record the species from the Cuban Cretaceous. Nakkady (1950) records *G. velascoensis* from the Cretaceous-Paleocene Esna shales of Egypt. Part of the controversy concerns the age of the Velasco shale of Mexico, which is thought to be, at least in part, Cretaceous by many authors. Dorr (in Muir, 1936) states that *G. velascoensis* occurs with *Globotruncana arca* in the Tampico Embayment region and that the forms were indigenous. In summation the geologic range of *G. velascoensis* is questionably Upper Cretaceous and definitely Paleocene and lower to middle Eocene.

GLOBOROTALIA VELASCOENSIS (Cushman) var. ACUTA (Toulmin), 1941
Plate 31, figs. 32–33

Globorotalia wilcoxensis Cushman and Ponton var. *acuta* TOULMIN, 1941, Jour. Paleontology, vol. 15, p. 608, pl. 82, figs. 6–8.
Globorotalia velascoensis (Cushman) var. *acuta* (Toulmin) GRIMSDALE, 1951, Proc. Third Pet. Congress, Section 1, Preprint 7, p. 9.

The writer agrees with Grimsdale that this variety is much closer to the species *G. velascoensis* than it is to *G. wilcoxensis*. The variety occurs commonly with *G. velascoensis* in the indurated *Globigerina* ooze from Hess Guyot and on Horizon Guyot and in the cores from MP 27. It is separated from *G. velascoensis* only by the fact that its sutures are not beaded. The geologic range of the variety is noted by authors to be Paleocene to middle Eocene.

GLOBOROTALIA WILCOXENSIS Cushman and Ponton, 1932
Plate 32, fig. 7

Globorotalia wilcoxensis CUSHMAN and PONTON, 1932, Cushman Lab. Foram. Res., Contr., vol. 8, p. 71, pl. 9, fig. 10.

This species is rare in the cores from MP 27. The geologic range of the species is Paleocene to middle Eocene. Type material from the U. S. National Museum was compared with the Mid-Pacific material.

Genus GLOBOTRUNCANA Cushman, 1927
GLOBOTRUNCANA ARCA (Cushman), 1926
Plate 29, figs. 1–3

Pulvinulina arca CUSHMAN, 1926, Cushman Lab. Foram. Res. Contr., vol. 2, pt. 1, p. 23, pl. 3, figs. 1 a–c.
Globotruncana arca (CUSHMAN), 1927, Cushman Lab. Foram. Res., Contr., vol. 3, p. 91, pl. 19, fig. 11.
Globotruncana arca (Cushman) BANDY, 1951, Jour. Paleontology, vol. 25, p. 509, pl. 75, figs. 1a–c.

This distinctive biconvex, double-keeled species ranges from the Campanian to the

end of the Maestrichtian in the Caucasus and is found in the Taylor and Navarro sediments of the Gulf Coast and adjacent areas. It is common in the cores at MP 27.

GLOBOTRUNCANA CALCARATA Cushman, 1927
Plate 29, figs. 4, 5

Globotruncana calcarata CUSHMAN, 1927, Contr. Cushman Lab. Foram. Res., vol. 3, p. 115, pl. 23, fig. 10a–b.
Globotruncana calcarata CUSHMAN, 1946, U. S. Geol. Survey Prof. Paper 206, p. 151, pl. 62, fig. 8.

A single specimen of this distinctively spined species was found in the mixed Upper Cretaceous to Recent fauna from MP 27-2.

GLOBOTRUNCANA CALICIFORMIS (de Lapparent), 1918
Plate 29, figs. 6–8

Rosalina linnei mutation *caliciforme* DE LAPPARENT, 1918, Carte geol. France Mem., p. 8, fig. 2j, pl. 1, fig. 2.
Globotruncana caliciformis (de Lapparent) CITA, 1948, Riv. italiana paleontologia anno 54, fasc. 4, p. 148–149, pl. 3, figs. 4a–c.
Globotruncana caliciformis (de Lapparent) BOLLI, 1951, Jour. Paleontology, vol. 25, p. 194, pl. 34, figs. 4–6.

This species is common in the mixed Upper Cretaceous to Recent fauna of MP 27-2. An identified specimen was sent to Dr. Hans Bolli in Trinidad who stated (personal communication, 23 February 1952) that it was conspecific with his Trinidad form.

GLOBOTRUNCANA CANALICULATA (Reuss), 1854
Plate 29, figs. 9, 10

Rosalina canaliculata REUSS, 1854, Akad. Wiss. Wien., Math.-naturwiss. Kl., Denkschr., vol. 7, pt. 1, p. 70, pl. 26, fig. 4.
Globotruncana canaliculata CUSHMAN, 1946, U. S. Geol. Survey Prof. Paper 206, p. 149, pl. 61, figs. 17 and 18.
Globotruncana canaliculata BANDY, 1951, Jour. Paleontology, vol. 25, p. 509, pl. 75, figs. 2a–c.

Forms which have nearly parallel sides and are double-keeled are usually placed in this species in American literature. There is a suspicion, however, that *G. canaliculata* and *G. linnei* (d'Orbigny) are the same (Glaessner, 1937; Bolli, 1951). As pointed out by Bolli (1951) a monographic revision will be necessary to solve some of these questions. This species is rare in the cores at MP 27.

GLOBOTRUNCANA CONTUSA (Cushman), 1946
Plate 29, figs. 14–16

Globotruncana arca var. *contusa* CUSHMAN, 1946, U. S. Geol. Survey Prof. Paper 206, p. 150–151, pl. 62, figs. 6a–b.
Globotruncana contusa (Cushman) CITA, 1948, Riv. italiana paleontologia, anno 54, fasc. 4, pp. 150–151, pl. 3, figs. 5a–c.
Globotruncana contusa (Cushman) BOLLI, 1951, Jour. Paleontology, vol. 25, p. 196, pl. 34, figs. 7–9.

This species is common in the mixed Upper Cretaceous to Recent fauna from MP 27-2. An identified specimen was sent to Dr. Hans Bolli in Trinidad who agreed that the form was conspecific with his Trinidad species.

GLOBOTRUNCANA FORNICATA Plummer, 1931
Plate 29, fig. 21

Globotruncana fornicata PLUMMER, 1931, Univ. Texas Bull. 3101, p. 198, pl. 13, figs. 4–6.
Globotruncana fornicata CUSHMAN, 1946, U. S. Geol. Surv. Prof. Paper 206, p. 149, pl. 61, fig. 19.

This biconvex, double-keeled species differs from *G. arca* in having strongly curved sutures on the dorsal side which give the chambers on that side a distinctive "sausage-shaped" appearance. The species is common in the cores at MP 27. This species is reported in the Taylor and Navarro sediments of the Gulf Coast and adjacent areas and from the Emscher to the Campanian in the Caucasus.

GLOBOTRUNCANA GANSSERI Bolli, 1951
Plate 29, figs. 18–20

Globotruncana gansseri BOLLI, 1951, Jour. Paleontology, vol. 25, p. 196, pl. 35, figs. 1–3.

This species is common in the mixed Upper Cretaceous to Recent fauna of MP 27-2. An identified specimen was sent to Dr. Hans Bolli in Trinidad who agreed (personal communication, 23 February 1952) that it was *G. gansseri*. He further stated that he had found *G. gansseri* in Upper Cretaceous Cuban material.

GLOBOTRUNCANA GLOBIGERINOIDES
Brotzen, 1936
Plate 29, figs. 17, 22

Globotruncana globigerinoides BROTZEN, 1936, Sveriges geol. Undersokning, ser. C, no. 396, Arsbok 30, no. 3, pl. 12, figs. 3a–c, pl. 13, fig. 3.
Globotruncana globigerinoides Brotzen, BOLLI, 1951, Jour. Paleontology, vol. 25, p. 198, pl. 35, figs. 16–18.

This species differs from species of *Globigerina* in having a faint double keel around the periphery of the globose chambers; it is especially close to *Globigerina rugosa* Plummer reported from the Navarro of Texas. The range of the species is reported by Glaessner (1937) as Coniacian-Santonian, but its occurrence in the cores at MP 27, together with distinctive species such as *G. arca* and *G. fornicata*, extend its range upward into the Campanian and Maestrichtian.

GLOBOTRUNCANA MARGINATA
(Reuss), 1845
Plate 29, figs. 23–25

Rosalina marginata REUSS, 1845, Verstein. bohm., Kreideformation, pt. 1, p. 36, pl. 8, figs. 54, 74; pl. 13, figs. 6–8.
Globotruncana marginata THALMANN, 1934, Eclogae geol. Helvetiae, vol. 27, p. 414.
Globotruncana marginata CUSHMAN, 1946, U. S. Geol. Surv. Prof. Paper 206, p. 150, pl. 62, figs. 1, 2.

This flat to biconvex, double-keeled species is distinguished by its inflated, globigerinid chambers. This species is reported from the Eagle Ford to the lower Navarro in the Gulf Coast and adjacent areas and from the Turonian-Santonian to Campanian in the Caucasus. Bolli (1951) places the form reported by Cushman (1946) in the *G. lapparenti bulloides* Vogler group and notes that this group is found in Trinidad from the Turonian to Maestrichtian. This species is common in the cores from MP 27.

GLOBOTRUNCANA ROSETTA
(Carsey), 1926
Plate 29, figs. 26–28

Globigerina rosetta CARSEY, 1926, Univ. Texas Bull. 2612, p. 44, pl. 5, figs. 3a–c.
Globotruncana rosetta WHITE, 1928, Jour. Paleontology, vol. 2, p. 286, pl. 39, fig. 1.

There is confusion between this species reported by authors from the American Cretaceous section and *G. stuarti* (de Lapparent). Two recent papers illustrate this confusion. Bolli (1951) places Cushman's figure 5 (1946, pl. 62, fig. 5) in *G. stuarti* and Bandy (1951) places the same figure in *G. rosetta*. Glaessner (1937, p. 41) probably illustrates the difference between these two species: *G. stuarti* is single-keeled and distinctly conical on the dorsal side; *G. rosetta* is flat to slightly convex on the dorsal side and is also single-keeled. To add to the confusion some authors include single-keeled forms similar to *G. stuarti* and *G. rosetta* in *G. arca*. For the present the writer is placing those forms with flat to "slightly" convex dorsal sides in the species *G. rosetta*.

GLOBOTRUNCANA STUARTI (de
Lapparent), 1918
Plate 29, figs. 11–13

Rosalina stuarti DE LAPPARENT, 1918, Carte geol. France Mem., p. 12, fig. 4, p. 13, fig. 5.
Globotruncana stuarti (de Lapparent) RENZ, 1936, Eclogae geol. Helvetiae, vol. 29, no. 1, p. 19, pl. 6, figs. 35–41; pl. 8, fig. 6.
Globotruncana stuarti (de Lapparent) GLAESSNER, 1937, Publ. Lab. Paleon. Moscow Univ., Studies in Micropaleontology, vol. 1, fasc. 1, p. 39, Taf. 1, figs. 14a–c.
Globotruncana stuarti (de Lapparent), BOLLI, 1951, Jour. Paleontology, vol. 25, p. 196, pl. 34, figs. 10–12.

This species is rare in the mixed Upper Cretaceous to Recent fauna from MP 27-2. See remarks under *Globotruncana rosetta* (Carsey).

GLOBOTRUNCANA VENTRICOSA
(White), 1928
Plate 29, figs. 29–31

Globotruncana canaliculata ventricosa WHITE, 1928, Jour. Paleontology, vol. 2, p. 284, pl. 38, fig. 5.
Globotruncana ventricosa BROTZEN, 1936, Sveriges geol. Undersokning, ser. C, no. 396, p. 171, pl. 13, figs. 4a–c, text fig. 63.
Globotruncana ventricosa CUSHMAN, 1946, U. S. Geol. Surv. Prof. Paper 206, p. 150, pl. 62, fig. 3. (copy of White's figure).

This species is distinguished by its flat dorsal side, double keel, and highly convex ventral side; it is common in the cores from MP 27. This species is reported from the Campanian of the Gulf Coast and adjacent regions, the Campanian and Maestrichtian of Trinidad and from the Coniacian to the Maestrichtian in the European section.

Family HETEROHELICIDAE
Genus GÜMBELINA Egger, 1899
GÜMBELINA COSTULATA Cushman, 1938
Plate 30, fig. 12

Gümbelina costulata CUSHMAN, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, p. 16, pl. 3, figs. 7–9.
Gümbelina costulata CUSHMAN, 1946, U. S. Geol. Surv. Prof. Paper 206, p. 108, pl. 46, figs. 10-12.

This costate species appears to be confined to the Campanian and Maestrichtian. It is common in the cores at MP 27.

GÜMBELINA CUBENSIS Palmer, 1934

Gümbelina cubensis PALMER, 1934, Mem. Soc. Cubana Hist. Nat., vol. 8, p. 74, text figs. 1–6.

This species is common in the cores on Horizon Guyot. Its geologic range in the Gulf of Mexico-Caribbean area is upper Eocene to upper Oligocene. It is interesting to note that this range extends the range of the genus *Gümbelina* to the upper Oligocene.

GÜMBELINA EXCOLATA Cushman, 1926
Plate 30, fig. 11

Gümbelina excolata CUSHMAN, 1926, Contr. Cushman Lab. Foram. Res., vol. 2, p. 20, pl. 2, fig. 9.

This species is rare in the mixed Upper Cretaceous to Recent fauna from MP 27-2. It is a larger and more coarsely ornamented form than *G. costulata*.

GÜMBELINA GLABRANS Cushman, 1938
Plate 31, figs. 5, 6

Gümbelina glabrans CUSHMAN, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, p. 15, pl. 3, figs. 1, 2.
Gümbelina glabrans CUSHMAN, 1946, U. S. Geol. Surv. Prof. Paper 206, p. 109, pl. 46, figs. 17, 18.

This species is rare in the indurated *Globigerina* ooze from Hess Guyot. It appears to be confined to rocks of Navarro age in the Gulf Coast area, but ranges from the Campanian to the Maestrichtian in the Pyrenees.

GÜMBELINA GLOBULOSA (Ehrenberg), 1854
Plate 30, fig. 15; plate 31, fig. 9

Textilaria globulosa EHRENBERG, 1854, K. preuss. Akad. Wiss. Berlin, Abh., p. 135, pl. 4, fig. 4b, 1834; Mikrogeologie, pl. 21, fig. 87.
Gümbelina globulosa EGGER, 1899, K. bayer. Akad. Wiss., Math.-naturh., Abt., Abh. Kl. 2, vol. 21, pt. 1, p. 32, pl. 14, fig. 43.
Gümbelina globulosa CUSHMAN, 1946, U. S. Geol. Surv. Prof. Paper 206, p. 105, pl. 45, figs. 9–15. (for complete synonymy see this paper).

This species is common in the Gulf Coast and adjacent regions in the Campanian and Maestrichtian. It is reported in the Pyrenees from the Coniacian to the end of the Danian and from the Midway of Mexico. It is common in the cores at MP 27 and from the sediments on Hess Guyot.

GÜMBELINA PLUMMERAE
Loetterle, 1937
Plate 30, fig. 10

Gümbelina plummerae LOETTERLE, 1937, Nebraska Geol. Surv. Bull., 2nd ser., Bull. 12, p. 33, pl. 5, figs. 1, 2.
Gümbelina plummerae CUSHMAN, 1946, U. S. Geol. Surv. Prof. Paper 206, p. 104, pl. 45, figs. 1–3.

This species is widely distributed in the Gulf Coastal Plain, Nebraska and Kansas. Kikoine (1948) reports it from the Campanian to the end of the Maestrichtian in the Pyrenees. This species is common in the cores from MP 27.

GÜMBELINA PSEUDOTESSERA
Cushman, 1938
Plate 30, fig. 14

Gümbelina pseudotessera CUSHMAN, 1938, Cushman Lab. Foram. Res. Contr., vol. 14, p. 14, pl. 2, figs. 19–21.
Gümbelina pseudotessera CUSHMAN, 1946, U. S. Geol. Surv. Prof. Paper 206, p. 106, pl. 45, figs. 16–20.

This species is rare in the cores from MP 27. The geologic range of the species is from the Austin to upper Taylor in the Gulf Coast and adjacent areas.

GÜMBELINA aff. G. MIDWAYENSIS
Cushman, 1940
Plate 31, figs. 7, 8

Gümbelina midwayensis CUSHMAN, 1940, Cushman Lab. Foram. Res., Contr., vol. 16, p. 65, pl. 11, fig. 15.

This form occurs rarely in the indurated *Globigerina* ooze from Hess Guyot. It is similar to Cushman's Alabama species except in size. The average dimensions of ten specimens from the Hess Guyot fauna are: length 0.35 mm., width 0.20 mm., thickness 0.15 mm. These dimensions are about twice

those of the Alabama species. Cushman noted the chambers of *G. midwayensis* as "slightly overlapping" whereas the overlapping on the MidPac specimens is marked. The writer considers the MidPac specimens to be either conspecific with *G. midwayensis* or very closely related.

GÜMBELINA STRIATA (Ehrenberg), 1838
Plate 30, fig. 13

Textilaria striata EHRENBERG, 1838, K. preuss. Akad. Wiss. Berlin, Abh., p. 135, pl. 4, 1a, 2a, 3a.
Gümbelina striata EGGER, 1899, K. bayer Akad. Wiss. Math.-naturh., Abt. Abh., Kl. 2, vol. 21, p. 33, pl. 14, figs. 37–39.
Gümbelina striata CUSHMAN, 1946, U. S. Geol. Surv. Prof. Paper 206, p. 104, pl. 45, figs. 4, 5.
Gümbelina striata BANDY, 1951, Jour. Paleontology, vol. 25, p. 510, pl. 75, figs. 8a–b, 9a–b.

This species is rare in the cores from MP 27, it is reported from the Austin to Navarro in the Gulf Coast and adjacent areas and from the Coniacian into the Maestrichtian of Europe.

GÜMBELINA ULTIMATUMIDA White, 1929
Plate 31, figs. 1–4

Gümbelina ultimatumida WHITE, 1929, Jour. Paleontology, vol. 3, p. 39, pl. 4, fig. 13.
Gümbelina pupa CUSHMAN (not Reuss), 1927, Jour. Paleontology, vol. 1, p. 157, pl. 27, figs. 6a–b.
Gümbelina ultimatumida CUSHMAN, 1946, U. S. Geol. Surv. Prof. Paper 206, p. 107, pl. 46, figs. 6, 7.

This species is very common in the indurated *Globigerina* ooze from Hess Guyot (MP 33 C) and is rare in the cores at MP 27. It is common in the Velasco and Mendez shales of Mexico and has been reported from the Upper Cretaceous and lower Tertiary of Trinidad and from the Upper Cretaceous to Eocene of New Jersey.

GÜMBELINA VENEZUELANA Nuttall, 1935

Gümbelina venezuelana NUTTALL, 1935, Jour. Paleontology, vol. 9, p. 126, pl. 15, figs. 2–4.

This species is abundant in the Eocene cores from Horizon Guyot.

Genus PSEUDOTEXTULARIA Rzehak, 1886
PSEUDOTEXTULARIA VARIANS Rzehak, 1895
Plate 30, fig. 9

Pseudotextularia varians RZEHAK, 1895, K. k. Naturh. Hofmus. Annalen, vol. 10, p. 217, pl. 7, figs. 1–3.
Pseudotextularia varians Rzehak CUSHMAN, 1946, U. S. Geol. Survey Prof. Paper 206, p. 110, pl. 47, fig. 4–9.

One specimen of this species was found in the mixed Upper Cretaceous to Recent fauna from MP 27-2.

Genus VENTILABRELLA Cushman, 1928
VENTILABRELLA AUSTINANA Cushman, 1938
Plate 30, fig. 7

Ventilabrella austinana CUSHMAN, 1938, Cushman Lab. Foram. Res., Contr., vol. 14, p. 26, pl. 4, fig. 19.
Ventilabrella austinana CUSHMAN, 1946, U. S. Geol. Surv. Prof. Paper 206, p. 111, pl. 47, fig. 16.

This species is rare in the cores at MP 27. The genus ranges from the Turonian to the end of the Maestrichtian and occurs in the sediments of the Gulf Coast and adjacent areas and in Europe.

VENTILABRELLA CARSEYAE Plummer, 1931
Plate 30, fig. 8

Ventilabrella carseyae PLUMMER, 1931, Texas Univ. Bull. 3101, p. 178, pl. 9, figs. 7–9, 10.
Ventilabrella carseyae CUSHMAN, 1946, U. S. Geol. Surv. Prof. Paper 206, p. 112, pl. 48, figs. 1–5.

This species is rare in the cores at MP 27; it is abundant in the rocks of Navarro age in the Gulf Coast and adjacent areas.

The following benthonic species is reported at this time because of its wide occurrence in the Mid-Pacific faunas and to call attention to its importance as a world-wide index fossil.

EPONIDES TRÜMPYI Nuttall, 1930
Plate 31, figs. 22, 23

Eponides trümpyi NUTTALL, 1930, Jour. Paleontology, vol. 4, p. 287, pl. 24, figs. 9, 13, 14.

This species occurs rarely in the indurated *Globigerina* ooze from Hess Guyot, in the cores from MP 27, and in the cores from Horizon Guyot. Glaessner reports this species from the Caucasus; it is common in the Gulf Coast and Caribbean area, and its occurrence in the Middle Pacific further establishes it as a world-wide index fossil. The geologic range is reported to be Paleocene, all of the Eocene, and questionably lower Oligocene.

NONION MICRUS Cole, 1928
Plate 30, fig. 4

Nonion micrus COLE, 1928, Bull. Am. Paleon., vol. 14, no. 51, p. 22, pl. 5, fig. 12.

One specimen assigned to this species occurred in the Eocene fauna from Horizon Guyot. For remarks concerning this species and *Globigerinella pseudovoluta* Bandy see comments under the latter species.

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STATISTICAL STUDY OF *OPERCULINA*

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ABSTRACT—*Operculina bartschi* var. *ornata* Cushman, *O. ammonoides* (Gronovius), and *O. complanata* subsp. *japonica* Hanzawa have been identified from a one and one-half inch stratum of the Tertiary Suva marls of the Tamavua Valley, near Suva, Viti Levu, in the Fiji group. Statistical studies of *Operculina complanata japonica* indicate the presence of two closely similar but distinct forms not hitherto recognized. These are thought to be microspheric and megalospheric forms of a dimorphic species. Statistical measurements and counts based on the last whorl suggest that all measurements and counts should be based on fixed points representing equivalent degrees of spiral growth. Data based on these points indicate that the onset of senility is marked by the production of strongly recurved septa, and occurs when the volume of protoplasm reaches an approximately constant and predetermined value. The rate of increase of number of chambers with growth has been found to vary directly with proloculum radius, and spiral angle, rate of change of spiral angle with growth, and number of chambers measured from the proloculum to vary inversely. It is demonstrated that in specimens with the same volumetric ratio of chamber increase these relationships are fundamental, and must occur in any shell coiled in a plane logarithmic spiral. The volumetric ratio of chamber increase has been found to vary inversely with strength of ornamentation and thickness of the shell. The effects of the variation in volumetric ratio are too slight to obscure the previous relationships in plots based on the assemblage.

INTRODUCTION

VARIOUS species of *Operculina* in recent years have received much attention from micropaleontologists, but because of difficulty in determining whether differences between specimens or groups are taxonomically significant, or are expressions of polymorphism or changes in environmental conditions, the genus is still in a somewhat unsatisfactory state.

Early in this investigation it became apparent that species vary widely in sutural ornamentation, degree of involution, tightness of spiral coiling, and number of chambers in the last whorl. This variation was described by Yabe and Hanzawa for a series of Recent and younger Tertiary specimens of *Operculina ammonoides* from Samoa and the Ryukyu Islands (Yabe and Hanzawa, 1925). Opinion, however, seems to be divided concerning the factors controlling this variation. Hofker (1927, p. 61), who has studied the Recent East Indian Operculinae from a biological viewpoint, regarded such variation as indicating trimorphism and differences in environment. He suggested that all species from that area, with the exception of *O. heterosteginoides* Hofker, should be identified as *O. complanata* (Defrance). Chapman and Parr (1938), on the other hand, working with assemblages of *O. victoriensis* Chapman from the Miocene of Victoria, admitted the presence of trimorphism in specimens from some localities but denied that the external characters of the test are in any way correlated with the size of the proloculum. Also, other authors have disclaimed the existence of trimorphism altogether, and have tended to regard all differences in ornamentation as specific or dimorphic. Bannink (1948), who disagreed with Hofker regarding trimorphism, suggested that the shell is so inherently variable that no "natural" specific divisions can be made. He proposed therefore that *Operculina* should be split into a series of empirical species based on the degree of involution and variations in the tightness of coiling, which characteristics he regarded as significant.

In view of the fundamental importance of reaching a correct understanding of the relationship between internal structure and external appearance, type of polymorphism, etc., it is surprising that no detailed statistical research into the variation of the contemporaneous forms comprising a single *Operculina* population has yet been undertaken. In no case have authors, with the

possible exception of Bannink, utilized statistical methods which might lead in some measure to solution of their problems. Even in Bannink's work it is evident that the number of specimens utilized was too small, and the statistical methods employed were too generalized to throw much light on questions of intraspecific variation, polymorphism, etc. Thus time has long been ripe for a statistical variation study, and when adequate material came to hand, the author undertook an investigation of this kind.

The material studied is an assemblage of Operculinae collected by Professor R. M. Shackleton from a tuff band in the later Tertiary Suva marls of the Tamavua Valley, near Suva, Viti Levu, in the Fiji group. The sample is representative of a stratigraphic thickness of only one and one-half inches, and, in view of the relatively rapid rate of accumulation of such sediment and the absence of features indicating redeposition, the specimens may be regarded as contemporaneous. The sample yielded the following larger Foraminifera:

Alveolinella quoyi (d'Orbigny)
Operculina bartschi var. *ornata* Cushman
Operculina ammonoides (Gronovius)
Operculina complanata subsp. *japonica* Hanzawa

Of these *O. ammonoides* and *O. complanata japonica* are the most abundant. Of the former, 497 specimens were present; of the latter, 258. *A. quoyi* was represented by 145 specimens, and *O. bartschi ornata* by only 7.

The Suva marls are considered by most authors (Ladd, 1934; Ladd and Hoffmeister, 1946; Cole, 1946; etc.) to be Tertiary *f-g* (Van der Vlerk and Umbgrove, 1927). Whipple (1934), on the evidence of the larger Foraminifera assigned them to Tertiary *e*, although the other fossils almost unanimously indicate a younger age. *A. quoyi*, a form not previously reported from Fiji, indicates, according to Van der Vlerk (1950), an age not greater than Tertiary *f2–3*, thus substantiating the views of Ladd, Hoffmeister, and others.

ACKNOWLEDGEMENTS

The author wishes to express his gratitude to Professor R. M. Shackleton of Liverpool for the specimens on which this report is based. Particular thanks are due to Professor A. Wood of the University College of Wales, Aberystwyth, for his suggestion of the problem and his helpful comments during the preparation of the manuscript.

SYSTEMATIC PALEONTOLOGY

OPERCULINA d'Orbigny 1826

Three quite distinct groups of Operculinae assigned to the previously mentioned species are present in the material from Fiji. No forms are transitional between them and they cannot be members of one comprehensive and variationally plastic group. For reasons stated subsequently (section on polymorphism), neither are these species believed to represent polymorphic forms of such a group. Finally, because they occur together in a contemporaneous assemblage, and probably lived together under closely similar environmental conditions, it is unlikely that their very marked and constant differences could have been produced by differential ecological stimuli.

The variation in *O. complanata japonica* is treated statistically. All three species are figured and described.

OPERCULINA BARTSCHI var. ORNATA Cushman, 1921

Plate 34, figs. 1–3

Operculina bartschi var. *ornata* CUSHMAN, 1921, U. S. Nat. Mus. Bull. 100, p. 378, pl. 74, figs. 1, 2.
Operculina costata H. DOUVILLÉ, 1911, Philippine Jour. Sci., ser. D, vol. 6, p. 56, pl. A, fig. 3.
Operculina costata var. *tuberculata* H. DOUVILLÉ, 1911, idem, p. 56, pl. A, fig. 4.
Operculina bartschi var. *ornata* YABE and HANZAWA, 1925, Tôhoku Imp. Univ., Sci. Reports, ser. 2 (Geol.), vol. 7, no. 2, p. 52, pl. 6, figs. 7, 11.
Operculina complanata HOFKER, 1927, part (not *Lenticulites complanata* Defrance), Part 1, Mon. 4, Siboga Exped., pt. 1, p. 61.
Operculina bartschi var. *ornata* YABE and HANZAWA, 1929, Tôhoku Imp. Univ., Sci. Repts, ser. 2 (Geol.), vol. 11, p. 184, pl. 18, figs. 10–12; pl. 19, fig. 3.
Operculina bartschi var. *ornata* YABE 1930, Tôhoku Imp. Univ., Sci. Reports, ser. 2 (Geol.), vol. 14, p. 39, pl. 16, figs. 6, 7.
Operculina bartschi CHAPMAN and PARR, 1938, Proc. Roy. Soc. Victoria, Australia, vol. 50, pt. 1 (new series), p. 293.
Operculina bartschi LADD and HOFFMEISTER, 1946, Bernice P. Bishop Mus., Bull. 181, p. 277, pl. 12, figs. h–k; pl. 14, fig. 1.

The test consists of three to five whorls of

arc-shaped chambers, and reaches some 5 mm. in larger diameter in fully grown specimens. It is strongly compressed, except in the central region, which is slightly thickened. The absence of a well-developed peripheral rim and the faintness of the spiral suture tend to give a somewhat lenticular appearance. The whorls increase rather rapidly in height with growth so that the outline tends to become ear-shaped. The slightly raised sutures are strongly reflexed, and ornamented with numerous beads of shell material. The walls of the later formed chambers are smooth, but in earlier whorls they are evenly covered with small calcareous granulations. In the central region the granulations become larger, and are only distinguished from those on the sutures with difficulty.

O. bartschi and its varieties *plana* and *ornata* were first described by Cushman in 1911, the types coming from the Recent seas of the Philippines. The Fijian specimens seem to correspond most closely with the latter variety.

According to Chapman and Parr (1938, pp. 292, 293) *O. bartschi plana* is the microspheric form of the species. *O. bartschi* and *O. bartschi ornata* are both stated to be megalospheric. The internal diameter of of the proloculum of two microspheric forms is given as 0.035 and 0.039 mm., and that of one megalospheric form (*O. bartschi*) as 0.231 mm. No measurement for that of *O. bartschi ornata* is recorded.

The equivalent measurements of six specimens of *O. bartschi ornata* from Fiji are 0.075, 0.080, 0.086, 0.087, 0.113 and 0.117, all lower than those reported for typical *O. bartschi*. Possibly two groups of forms are represented by these Fijian specimens, one having prolocula about 0.081 and the other about 0.115 mm. in internal diameter. The wide range of proloculum sizes exhibited by other megalospheric Operculinae dealt with in this paper, however, makes it seem more likely that the grouping about these two values is fortuitous. Differences in internal proloculum diameter are not reflected by differences in external appearance.

This species may be distinguished from *O. complanata japonica* by the lack of a well-marked peripheral rim, the indistinctness of the spiral suture, and the strong recurvature of the septa. It differs from *O. ammonoides* by its greater size, more complanate shape, evolute nature of coiling, lack of a distinct peripheral rim, and shape of the septa.

OPERCULINA AMMONOIDES (Gronovius), 1781
Plate 34, figs. 4–6

Nautilus ammonoides GRONOVIUS, 1781, Zoophyracium Gronivianum exhitens Animalia Quadrupeda, etc., p. 282, pl. 19, figs. 5, 6.
Operculina (*Assilina*) *discoidalis* D'ORBIGNY, 1826, Ann. Sci. Nat., Paris, ser. 1, vol. 7, p. 296, modèle no. 88.
Operculina gaimardi FORNASINI, 1903, Bull. Geol. Soc. Italia, vol. 22, p. 396, pl. 14, fig. 4.
Assilina nitida FORNASINI, 1903, Bull. Geol. Soc. Italia, vol. 22, p. 397, pl. 14, fig. 11.
Operculina granulosa var. *niassi* Verbeek, VERBEEK and FENEMMA, 1896, Description géologique de Java et Madoura, Amsterdam, p. 1158, pl. 9, figs. 128–131.
Nummulites subniassi H. DOUVILLÉ, 1911, Philippine Jour. Sci., ser. D, vol. 6, p. 53, text fig. 1.
Operculina discoidalis CUSHMAN, 1921, U. S. Nat. Mus. Bull. 100, p. 379.
Operculina discoidalis var. *involuta* CUSHMAN, 1921, idem, p. 380, text fig. 16.
Operculina (*Operculinella*) *venosa* YABE and HANZAWA, 1925, (not *Nautilus venosus* Fichtel and Moll), Tôhoku Imp. Univ. Sci. Reports, ser. 2 (Geol.), vol. 7, p. 49, pl. 5, figs. 1–27; pl. 6, figs. 1–5; pl. 8, figs. 1–10.
Operculina complanata HOFKER, 1927, part (not *Lenticulites complanata* Defrance), Part 1. Mon. 4, Siboga Exped., pt. 1, p. 61.
Operculina philippinensis YABE, 1930 (not *Operculina philippinensis* Cushman), Tôhoku Imp. Univ., Sci. Reports, ser. 2 (Geol.), vol. 14, p. 40, pl. 12, fig. 9.
Operculina ammonoides CHAPMAN and PARR, 1938, Proc. Roy. Soc. Victoria, Australia, vol. 50, part 1 (new series), pp. 290–292, pl. 17, figs. 12–16.
Operculina venosa ABRARD, 1946 (not *Nautilus venosus* Fichtel and Moll), Ann. Paleont., vol. 32, p. 12, pl. 1, figs. 5, 6.

The test is small, attaining at most only 3 mm. in larger diameter. All specimens are rounded, strongly biconvex, and bordered by well-marked peripheral rims. The spiral angle[1] is large (about 87 degrees), and the whorls increase very slowly in height as they are added. The chambers are subrectangular and numerous. The chamber walls are usually smooth, although in the

[1] (Not to be confused with the spiral angle of a gastropod. In a logarithmic spiral the tighter the coiling, the greater the spiral angle.)

initially formed portions of the test they may be finely beaded. The umbilicus may be either open or occupied by a large bead of shell material.

Overlapping of the whorls varies considably. At one extreme are forms essentially nummulitic, both externally and internally, which are transitional into others indistinguishable from *O. discoidalis involuta*.

The sutures are only slightly recurved, curvature being greatest at their distal ends. They may be flush with the chamber walls, but commonly they are limbate and raised, and strongly beaded. Limbation in some specimens is extremely strong, the beads are very large and occasionally only four or five make up the length of the suture.

Available specimens, although quite variable, do not exhibit the great range described and figured by other authors (Yabe and Hanzawa, 1925; Hanzawa, 1935; Chapman and Parr, 1938). Specimens with whorls widening rapidly, giving a thin ear-shaped test, which have been demonstrated to be transitional with the typical *O. ammonoides*, do not occur in the Fijian material. They were referred by Chapman and Parr (1938, pl. 17, fig. 15) to *O. gaimardi* d'Orbigny. Another extreme variant absent from this material has whorls which increase in height very slowly, but rapidly become evolute. It occurs with typical forms in Japan and is transitional with them (Yabe and Hanzawa, 1925, pl. 5, figs. 5, 12–14, 21, 23–27; pl. 6, figs. 1–3; pl. 7, figs. 4, 6; Hanzawa, 1935, pl. 1, figs. 31–34). This undoubtedly is the form referred by d'Orbigny to his *Assilina nitida*.

According to Hofker, variants of this species represent the A1 and A2 forms of *O. complanata*. This view is completely rejected.

The internal diameter of the proloculum of four specimens of *O. ammonoides* was reported by Chapman and Parr (1938, p. 291) as 0.017, 0.031, 0.038, and 0.048 mm. The last is for the *O. gaimardi* form, which presumably was assumed to be microspheric. Equivalent measurements of Fijian specimens range between 0.047 and 0.088 mm. So far as can be judged, these measurements are comparable to those of specimens from the Ryukyu Islands, Formosa and Japan.

No specimens of the *O. gaimardi*-type occur in the Fijian material. No undoubtedly microspheric forms have been found, but this may be because only a relatively small number were sectioned.

This species can be distinguished from *O. complanata japonica* by its smaller size, biconvex shape, and the strong involution of its early whorls, and from *O. bartschi ornata* by these same features and also by its well-marked peripheral rim.

OPERCULINA COMPLANATA subsp. JAPONICA (Hanzawa)

Plate 33, figs. 1–12; plate 34, figs. 7, 8

Operculina complanata subsp. *japonica* HANZAWA, 1935, Tôhoku Imp. Univ., Sci. Reports, ser. 2 (Geol.), vol. 18, pp. 18–22, pl. 1, figs. 4–28.

Operculina complanata YABE, 1918, idem, vol. 4, p. 120, pl. 17, figs. 1–7.

Operculina complanata var. *granulosa* YABE, 1918 (not *Operculina granulosa* Leymerie), idem, vol. 4, p. 121, pl. 1, fig. 7.

Operculina sp. YOSHIWARA, 1901, Jour. Coll. Sci., Tokyo, vol. 16, art. 1, part 1, p. 14, pl. 1, fig. 2.

Operculina complanata SCHUBERT, 1911 (part) abh. d. k. k. Geol. Reichsanstalt, vol. 20, no. 4, pp. 96, 97, pl. 2, fig. 3; text fig. 12a.

Operculina complanata var. *japonica* LADD and HOFFMEISTER, 1946, Bernice P. Bishop Mus., Bull. 181, p. 278, pl. 12, figs. d–g; pl. 13, figs. f–i.

Operculina complanata var. *granulosa* ABRARD, 1946, (not *Operculina granulosa* Leymerie) Ann. Paleont., vol. 32, p. 11, pl. 1, fig. 2.

The variations of this inconstant species range between well-marked limits. Individual specimens, which are so diverse externally, all possess, however, certain characteristics both demonstrating their mutual relationships and differentiating them from the other associated species.

The moderate-sized test (up to 6.0 mm. in larger diameter) is complanate and ovate. Its periphery is furnished with a well-marked rim or lip, which sometimes is thicker than the central portion of the test. The sutures are limbate, raised and beaded, most markedly in the earlier formed whorls. They are initially radially directed, but become sharply reflexed at their distal ends. In a few specimens they are evenly reflexed throughout their length. The chamber walls are smooth and unornamented in the adult whorls but in the first two they are strongly inflated and granulated, and occasionally bear a few larger papillae concentrated in the region immediately surrounding the proloculum. The center of the test may be

occupied either by a central boss of calcareous shell material, or by an indistinct agglomeration of papillae. The chambers are numerous, and increase in size rather rapidly as they are added. The spiral angle varies somewhat, but it remained more or less constant during the growth of each individual.

O. complanata japonica can be distinguished from *O. bartschi ornata* by its well-developed keel, distinct spiral sutures, and shape of septal sutures, and from *O. ammonoides* by its greater size, strong lateral compression, and evolute coiling.

VARIATION OF *OPERCULINA COMPLANATA JAPONICA*

EXTERNAL VARIATION

This subspecies, like other forms of *Operculina*, varies somewhat in number of whorls and maximum diameter. The number of whorls is revealed accurately only in sections, but the approximate number can be determined externally. This number is to some extent a function of the maximum diameter because with specimens having similar spiral angles, increase in the number of whorls must be accompanied by an increase in size. This relationship is considered further in the section on internal variations.

The most striking external variation is in development of sutural ornamentation. In some specimens the ribs are thin and delicate, and the barely perceptible beads are few (plate 33, figs. 10–12). In others the sutures are thickened, strongly raised, and ornamented with large tuberculations which tend to fuse in places producing coarse irregular ridges (plate 33, figs. 1–3). There appears to be complete morphological transition between these types, and one grades imperceptibly into the other (plate 33, figs. 4–9). In all cases the ornamentation is coarsest in the central area and continues as granulations or papillae scattered indiscriminately over the general surface.

The coarseness of the sutural ornamentation is directly correlated with the thickness of the peripheral rim and the general robustness of the shell as a whole. No specimens have been found with well-developed peripheral rims and delicate sutural ornamentation, or with weakly-developed rims and coarse ornamentation.

The shape of the septa varied somewhat during growth. In early stages septa are radially directed, only becoming reflexed distally. This reflexure generally is not visible in the earlier formed whorls, because the later ones embrace the marginal cord. In late growth stages, however, the septal character may change. The reflexure gradually migrates proximally, and septa become initially oblique, and evenly recurved throughout their length. This change never occurs in the early growth stages, but the position where it is initiated varies. Some shells were completed before the change began. In others the septa of the whole of the last whorl are evenly recurved. This variation is completely independent of the coarseness of the sutural ornamentation and was governed primarily by variations in the spiral angle. Because the point of initiation of change in septal shape can only be ascertained in thin sections, further consideration is included under the topic of internal variations.

Two other quite variable characters greatly influence the external appearance. These are the spiral angle of coiling, and the number of chambers in a whorl. As determined exteriorly the former varies between 76 and 82 degrees. The chambers per whorl can not be counted accurately in solid specimens. There seems to be no correspondence between differences in spiral angle and sutural ornamentation, thickness of rim, etc., and the spiral angle varies greatly in both coarsely and delicately ornamented specimens.

Finally, considerable differences mark the initial portion of the test. In some specimens the center is occupied by a variable boss of shell material (plate 33, figs. 1–6), but in others this is replaced by closely set papillae (plate 33, figs. 7–12). A small boss may be difficult to recognize on well-ornamented specimens.

The presence or absence of a central boss is not correlated with the size of the spiral angle but it is related to the coarseness of sutural ornamentation, thickness of peripheral rim, etc. Well-ornamented specimens possess well-developed central bosses, and weakly ornamented ones do not. Intermedi-

ate specimens may or may not possess a central boss, but as a rule those which do have more coarsely tuberculated sutures and thicker rims than those which do not. The actual size of the boss, however, does not seem to be significant.

The various forms of *O. complanata japonica* may be classified as follows:

Group 1.
- (a) Central boss absent
- (b) Sutures weakly to moderately raised and ornamented
- (c) Shell as a whole not strongly constructed
- (d) Peripheral rim thin to moderate.

Group 2.
- (a) Central boss present
- (b) Sutures moderately to strongly raised and ornamented
- (c) Shell as a whole strongly constructed
- (d) Peripheral rim moderate to thick.

In all, 126 specimens of group 1 were found, and 128 of group 2. Extremely coarse sutural ornamentation and related features occur in 11 of the latter, and 14 very weakly ornamented specimens are included in the former group. Typical specimens of group 1 are illustrated on plate 33, figures 7–12; figures 1–6 show typical specimens of group 2. Extreme forms of the two groups are illustrated in figures 10–12 and 1–3 respectively.

INTERNAL VARIATIONS

Method of investigation.—All 254 specimens were sectioned in the plane of coiling.

Sectioning of opaque larger Foraminifera for statistical treatment is difficult, and to avoid considerable error in measuring small differences in diameter the center of the proloculum must be cut. Good results however were obtained by the following method.

Specimens were mounted flat on a glass slide in Canada balsam in the usual way and were ground by hand. Progress was checked under strong illumination with a binocular microscope fitted with an eyepiece micrometer. A 32 mm. objective and a ×15 eyepiece were satisfactory. When the apparent proloculum diameter reached its maximum the specimen was reversed on the slide and the other side ground down.

As previously mentioned, two of the most variable features are the spiral angle of coiling and the number of chambers per whorl. Although most authors have considered these to be specifically diagnostic, looseness and lack of coördination in descriptions have been common. The size of the spiral angle usually has been vaguely expressed in the form "whorls widening rapidly," or, more exactly, "height of last chamber in second (third, fourth, etc.) whorl is __mm." It also has been stated as the ratio of the height of one whorl to another, the last whorl commonly having been taken as one of them. The number of chambers also almost invariably was counted in the last whorl. Thus the last whorl has been treated as though it were particularly diagnostic, but this appears to be entirely unwarranted. It is seldom stated whether the "last whorl" is the last complete whorl measured from the proloculum forwards, or the last whorl as measured from the final chamber backwards. In either case measurements and counts depend on the number of whorls present. This number in turn depends on the inherent variability of the organism, the state of development on incorporation into the enclosing sediment, and damage sustained by the last chambers, and therefore such measurements have little comparative value. Their only virtue is that they are easy to make. In this study the "last whorl" was not used as a basis for comparison.

The curvature of the shell of *Operculina* approximates a logarithmic spiral, and radial growth bears a constant relationship to growth in the direction of the curve (D'Arcy Thompson, 1942, pp. 756, 757). It follows, therefore, that this relationship is a function of the spiral angle. If reference points for measurements and counts are taken at fixed distances from the origin of the curve (the proloculum) around the spiral, the numerical data are strictly comparable because they represent an equal degree of spiral growth for all specimens. By comparing measurements and counts at two or more such points on the same spiral, the changing relationships during the growth of an individual can be determined. Finally, comparisons of such data from several specimens may reveal additional possible differences.

In this study reference points were se-

lected at 6 and 12 mm. measured forward from the proloculum along the spiral. These are simply convenient distances, large enough to insure measurable variations and small enough to fall within the limits of all but the smallest specimens.

The reference points were marked on drawings of the sections, uniformly enlarged to about 12 diameters (for description of apparatus used, see Wood, 1945) and all measurements and counts were made on the drawings. Sections showing marked distortion or irregularity of growth were not used. The data are represented graphically in scatter plots (Day, 1915; Swinnerton, 1940) and frequency diagrams. The spiral angles were obtained graphically from the equation:

$$\frac{H}{L} = \frac{2\pi \operatorname{Cot}\alpha}{\operatorname{Sec}\alpha(1-2\pi \operatorname{Cot}\alpha)}$$

where H is the whorl height, L the distance of reference point from the proloculum measured along the spiral, and α is the spiral angle.

Polymorphism.—Hanzawa, who presumably believed that the species of *Operculina* are dimorphic, stated (1935, p. 19) that all specimens of *O. complanata japonica* so far found are megalospheric and reported the diameter of the proloculum to be 0.11 mm. This statement implies that either the microspheric individuals are very rare and have not yet been found, or that they are recognized under another specific name. If Hanzawa was correct, the former explanation is the more likely because the latter seems improbable when the compositions of the *Operculina* assemblages are considered. Among the Fijian specimens the only ones which might conceivably represent the microspheric generation are identified as *O. ammonoides* and *O. bartschi ornata*, but neither of these invariably accompanies *O. complanata japonica* in other assemblages. Often they occur alone, or in association with entirely different forms. As an alternative, is it possible that the differences between the microspheric and megalospheric forms are so slight that they have been confused?

When the Fijian specimens were first sorted on the basis of ornamentation it seemed probable that the two groups described above indicated dimorphism. The frequency curve of proloculum radius shown in figure 1 substantiates this conclusion. The curve for all specimens in the sample has two well-marked peaks, at about 0.045 and 0.060 mm. This is broken down into two curves for the separate groups. These curves are similar to each other and closely approximate to normal distribution curves. Their peaks are identical to those of the single curve. This close correspondence in shape, the horizontal separation of maxima and lack of subsidiary peaks shows that the grouping based on ornamentation is real. It probably distinguishes two different generations of the species.

The recognition of two generations does not solve the problem completely because these might represent microspheric and megalospheric forms of a dimorphic species, or two megalospheric forms of a trimorphic species.

In most larger Foraminifera the megalosphere is at least twice as large as the microsphere. The larger proloculum of the Fijian specimens is on an average only one-third larger than the smaller, and this suggests that both might be megalospheric. The dimensions are so variable, however, that this may not be significant. Also, the large number of specimens with small prolocula suggests that these are not microspheric. The proportion of microspheric specimens in an assemblage, however, is not always low, especially in the genus *Operculina*. Chapman and Parr (1938, p. 293), discussing polymorphism of Australian forms of *O. bartschi*,

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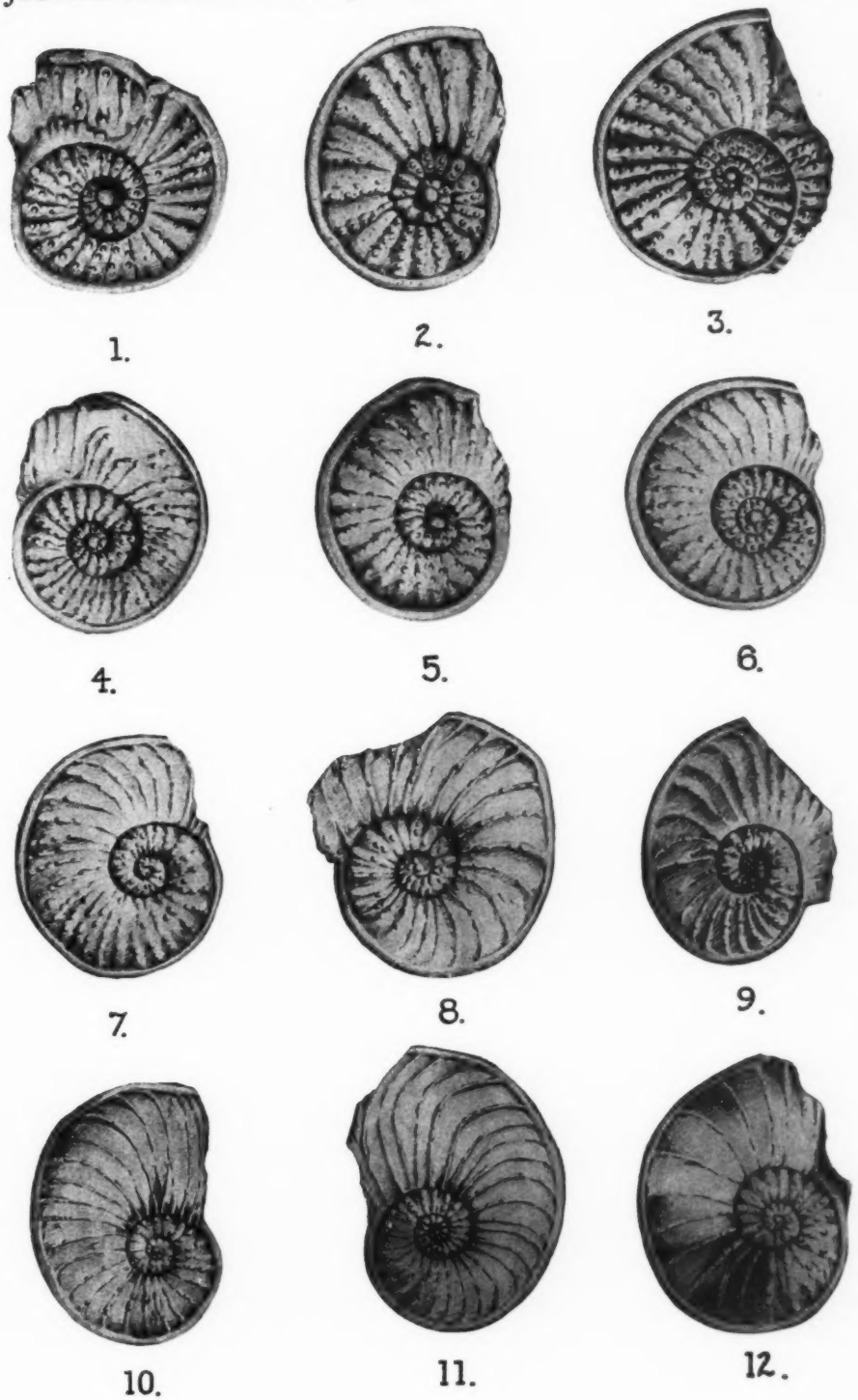
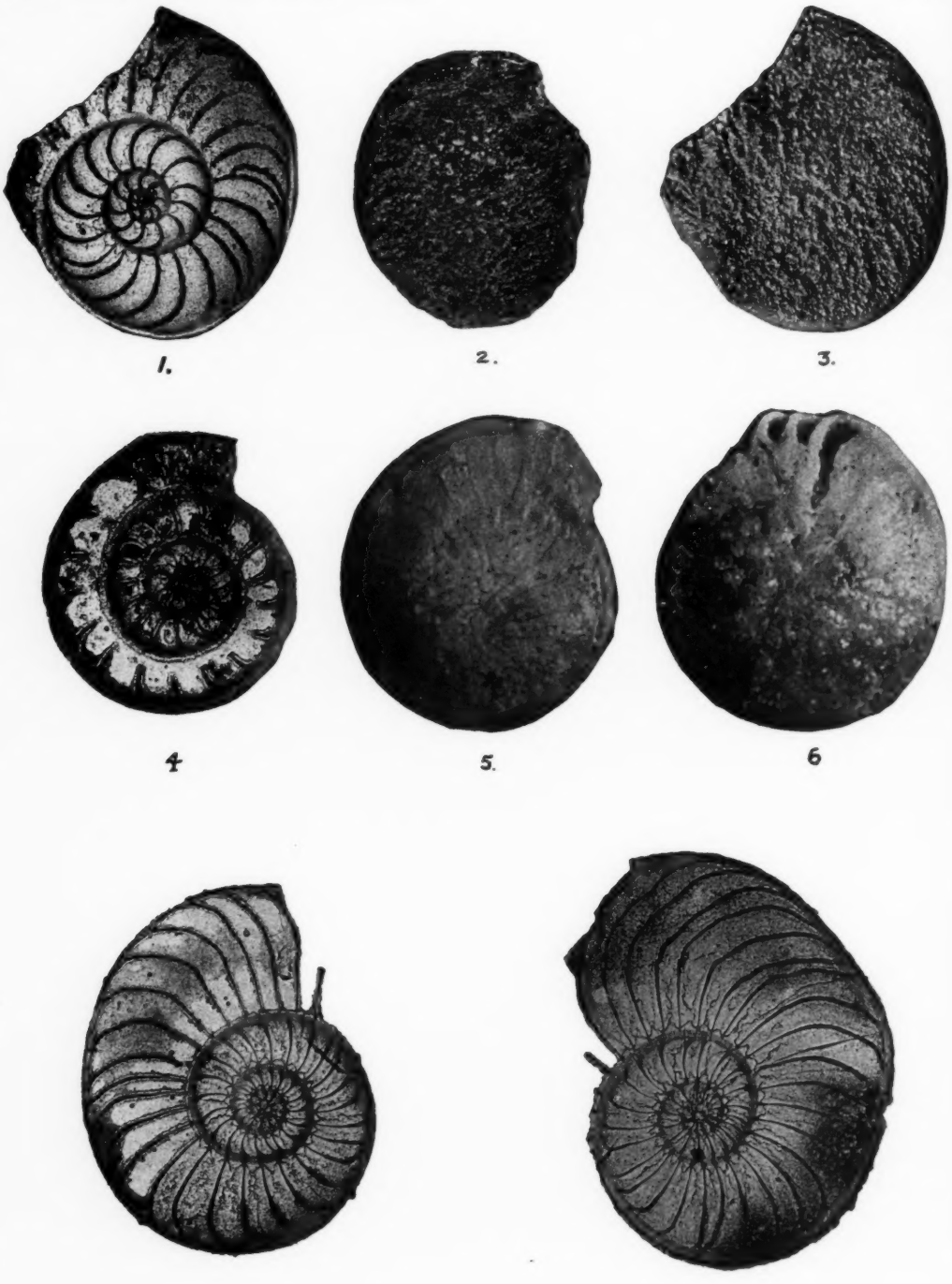
EXPLANATION OF PLATE 33

FIGS. *1–12*—*Operculina complanata* (Defrance) subsp. *japonica* Hanzawa, all ×9. Selected specimens showing range of variation in external ornamentation and its relationship to dimorphism. *1–3*, specimens showing extreme megalospheric ornamentation. Cat. Nos. 2179, 2092 and 2178. *4–6*, megalospheric specimens showing intermediate ornamentation. Cat. Nos. 2083, 2177 and 2088. *7–9*, microspheric specimens showing intermediate ornamentation. Cat. Nos. 2132, 2133 and 2134. *10–12*, specimens showing extreme microspheric ornamentation. Cat. Nos. 2074, 2075 and 2169. (p. 241)



Carter, Statistical Study of *Operculina*



Carter, Statistical Study of *Operculina*

noted that the microspheric generation, which is always smaller than the megalospheric, is more than twice as common.

If the two generations of the Fijian *O. complanata japonica* are both megalospheric, where is the microspheric form? The possibility that it has been identified as another species already has been considered and rejected. Perhaps it is so rare that it is absent from the material examined, but in view of the large number of specimens sectioned this is unlikely. It is also possible that microspheric individuals have been included in group 1. If so they must be too rare to produce any recognizable subsidiary peak on the curves, and they must be indistinguishable both externally and internally except for proloculum size. This also seems improbable.

On the whole, the evidence slightly favors the conclusion that the two forms of *O.*

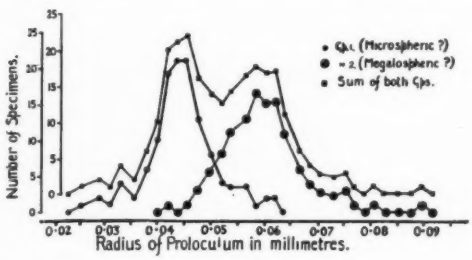


FIG. *1*—Frequency diagram showing variation in maximum internal proloculum radius of *Operculina complanata japonica*

complanata japonica from Fiji are microspheric and megalospheric generations of a dimorphic species. The author accepts this view.

Maximum diameter and number of whorls.—In figure 2 the number of whorls forming the complete shell is plotted against its maximum diameter. These variables are of course directly proportional. The wide scattering results from complications introduced by variations in the spiral angle. The diagram shows, however, that there is little significant difference between the limits of the microspheric and megalospheric forms. Therefore, in this case the microspheric shell is not significantly larger than the megalospheric, nor does it consist of a larger number of whorls.

Shape of septa.—As previously men-

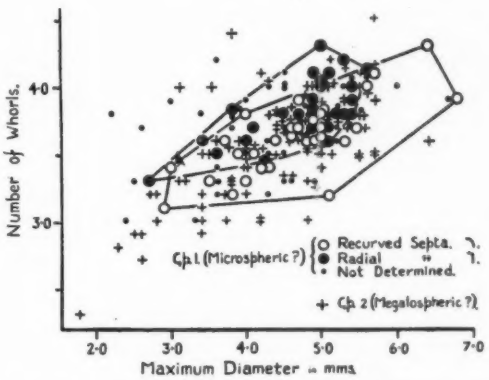


FIG. *2*—Scatter diagram showing relationship between maximum shell diameter, number of whorls, and form of late ephebic septa in *Operculina complanata japonica*.

tioned, the shape of the septa changed during growth of the individual. In the initial nepionic stage the septa are short and convex towards the aperture. They then become straight, radially directed, and recurved only at their extreme distal ends. In some specimens this septal type persisted through all the post-nepionic stages (plate 34, fig. 7), but in others it was modified in the late ephebic stage. In them recurvature gradually spreads inwards from the distal end and finally produces septa which are wholly recurved and often obliquely directed away from the aperture even at their proximal ends (plate 34, fig. 8). Transition between these types is gradual or sometimes

EXPLANATION OF PLATE 34

FIGS. *1–3*—*Operculina bartschi* Cushman var. *ornata* Cushman, all ×9. *1*, *3*, sagittal section and specimen before sectioning. Cat. No. 2302. *2*, Cat. No. 2304. (p. 239)

4–6—*Operculina ammonoides* (Gronovius), ×20. *4*, sagittal section, Cat. No. 4007; *5*, *O. discoidalis* var. *involuta* type, Cat. No. 4032; *6*, nummulitic type, Cat. No. 4033. (p. 240)

7–8—*Operculina complanata* (Defrance) subsp. *japonica* Hanzawa. Sagittal sections ×10. Cat. Nos. 2006 and 2074. (p. 241)

even slightly oscillatory, and the position of initiation of the final type cannot be defined by a point on the spiral. If a fixed point be taken, however, it is relatively simple to decide on which side of it transition occurs. Thus specimens can be separated into two groups, one in which the septa at the fixed point are radial, and the other in which they are recurved. This has been done with reference to a point 16 mm. from the proloculum, so that the groups contain approximately the same number of individuals. This point falls outside the limits of the spiral of many specimens. If these possess recurved septa they were assigned

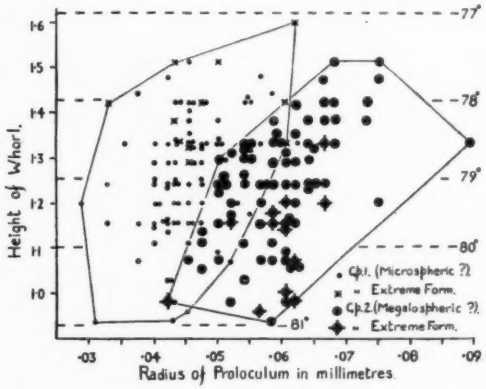


FIG. 3—Scatter diagram showing relationship between maximum internal proloculum radius and whorl height at point 12 mm. from proloculum measured around the spiral. The whorl height is also expressed in terms of spiral angle of coiling, in degrees.

to the appropriate group, but if not, they were ignored because their proper group could not be determined.

Relationships between number of whorls, maximum diameter and form of septa is shown in microspheric specimens only. The form of septa of megalospheric individuals is not indicated in order to avoid a multiplicity of symbols and resultant lack of clarity. The distribution for megalospheric specimens is almost identical.

This scatter plot demonstrates a definite relationship between septal form, on the one hand, and number of whorls and maximum diameter on the other. The distribution shows that, in shells of the same diameter, those with a large number of whorls tend to have radial septa in the late ephebic stage, and those with a small number of whorls tend to develop reflexed septa. In shells of the same diameter, the number of whorls is a function of the average spiral angle of coiling. Therefore the shape of the septa at the reference point also is a function of this factor. Recurved septa appear at an earlier growth stage in specimens with a low spiral angle than they do if this angle is large.

The appearance of recurved septa may mark the onset of senility, for it often is accompanied or rapidly followed by a change from increase to decrease in whorl height, which usually continues to the last chamber. The septa themselves in this last stage tend to become somewhat irregular and often crowded. Recurved septa of the same general type also always occur in distorted portions of the shell.

Probably senility was attained and recurved septa were produced when the protoplasm of an individual reached a predetermined and approximately constant volume. This would explain the appearance of recurved septa at earlier stages of spiral growth in specimens whose whorl height has increased rapidly.

Spiral angle and whorl height.—The coiled shell of *Operculina* approximates a logarithmic spiral. This was checked by fitting enlarged drawings of sagittal sections to accurately drawn spirals with angles varying between 76 and 82 degrees. Some shells show obvious irregularities of growth. Distortions are especially frequent immediately following the proloculum, and in the gerontic stages. In general, however, the spiral angle of any individual either is reasonably constant, or changes gradually.

In figure 3 the whorl height at the 12 mm. reference point is plotted against the internal radius of the proloculum. This diagram shows that, although both microspheric and megalospheric specimens vary considerably in spiral angle, their ranges of variation are similar. The greatest concentrations and, to a lesser extent the complete distribution, show a rough but unmistakable inverse relationship between the radius of the proloculum and the spiral angle. The same relationship also is apparent in a plot based on the 6 mm. reference point.

Figure 4 is a plot of the internal radius of the proloculum against the ratio of whorl heights measured at the two reference points. It is similar in many respects to figure 3. Variation of the ratio, although large, is almost identical in the microspheric and megalospheric groups. The concentrations of specimens demonstrates a direct relationship between the variables. This is also reflected, to a smaller degree, by the elongated trends of the scatter peripheries but, because these are controlled by a few outlying individuals, such trends cannot be expected to indicate the relationship accurately.

The distance from the proloculum to the second reference is exactly twice that to the

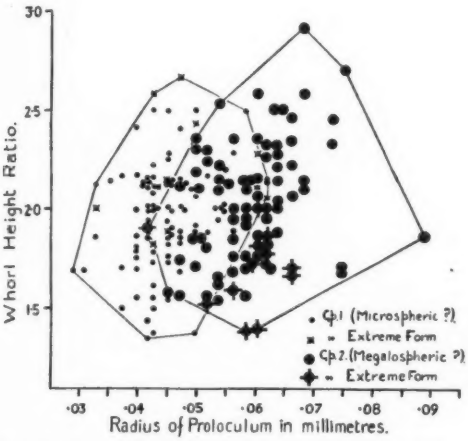


FIG. 4—Scatter diagram showing relationship between maximum internal proloculum radius and whorl height ratio at points 6 mm. and 12 mm. from proloculum measured around spiral.

first, but the ratios range from 1.35 to 2.90. Therefore, the rate of increase of whorl height changes from a deceleration to an acceleration with increase in proloculum radius.

Number of chambers.—The number of chambers between the proloculum and the 12 mm. reference point is plotted against the internal radius of the proloculum in figure 5. It demonstrates an inverse relationship between the variables and reveals the similarity in variation of the dimorphs. Similar relations are shown by a plot of counts to the 6 mm. reference point.

In figure 6 the ratio between numbers of

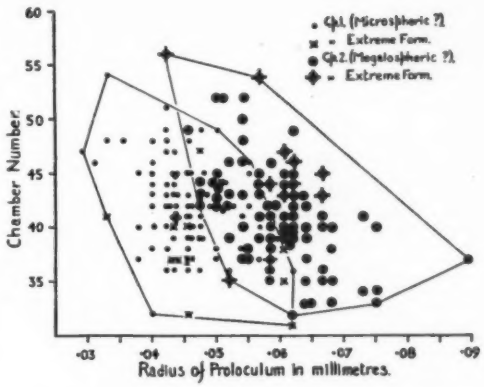


FIG. 5—Scatter diagram showing relationship between maximum internal proloculum radius and number of chambers between proloculum and point 12 mm. from proloculum measured around spiral.

chambers from the proloculum to the two reference points is plotted against the internal radius of the proloculum. This diagram demonstrates a direct relationship between the variables and, thus, resembles figure 4. It differs from figure 5 in showing a somewhat greater range of variation in the megalospheric than in the microspheric group.

Relationship between whorl height and number of chambers.—Four fundamental relationships between the internal radius of

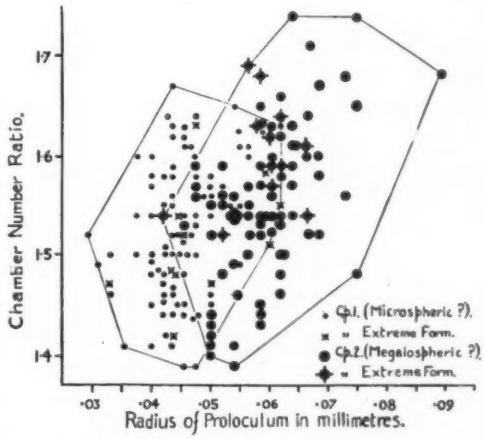


FIG. 6—Scatter diagram showing relationship between maximum internal proloculum radius and ratio between number of chambers from proloculum to points 6 mm. and 12 mm. from proloculum measured around spiral.

the proloculum and other internal structures of *O. complanata japonica* have been determined as follows.

The greater the proloculum radius:

(a) The greater the whorl height at a fixed point from the proloculum measured around the spiral,

(b) The smaller the number of chambers between the proloculum and such a fixed point,

(c) The greater the ratio between the whorl heights at two such fixed points, and,

(d) The greater the ratio between the number of chambers between the proloculum and two such fixed points.

These relationships are represented diagrammatically in figure. 7. Lack of knowledge concerning the laws which control the growth, structure, and general physiology of Foraminifera renders uncertain any interpretation of these relationships, but because the arguments involved are those of common sense, and only one assumption need be made, the author feels justified in an attempt.

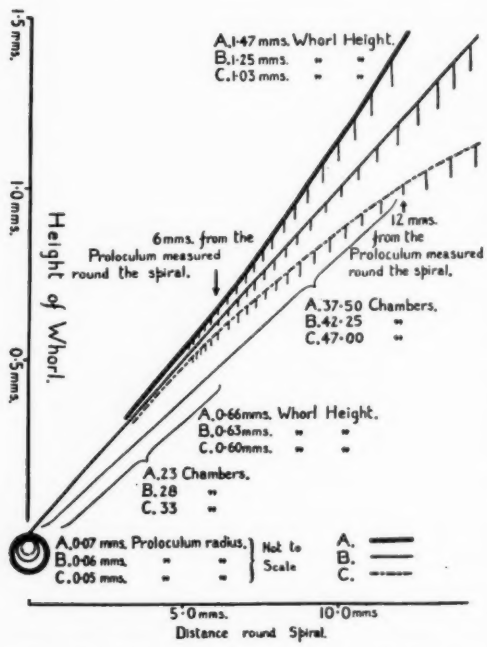


FIG. 7—Diagrammatic representation of relationships between maximum internal proloculum radius, whorl height, number of chambers, whorl height ratio, and chamber number ratio. The volumetric increase ratio of successive chambers is assumed to be constant.

It is reasonable to suppose that in *Operculina* as in other chambered spirally coiled shells, the volume of each chamber bears a constant ratio to that of the next, and that the rate of increase at any point is proportional to the total volume of all preceding parts of the shell (D'Arcy Thompson, 1942, p. 860). If so, the volume of succeeding chambers will be larger in forms with a large proloculum than in forms with a small proloculum. Therefore, if the spiral angle is the same, septa will be more widely spaced in that which has the largest proloculum. From this it follows that there will be fewest chambers per unit distance around the spiral in forms with the largest prolocula. This is shown in figure 7, a graphical representation of the four relationships based on the best average values for the megalospheric form. At the 6 mm. reference point the range of variation in whorl height is so small as to be almost inappreciable, and therefore the number of chambers between the proloculum and this point always is inversely proportional to the size of the proloculum. At the 12 mm. reference point, however, the range of variation in whorl height has become appreciable, and tends to introduce modifications. In forms whose proloculum radius is large, the rate of increase in whorl height accelerates with growth. If the volume relations remain constant, an increase in whorl height must be compensated by a proportional decrease in chamber width, and septa will be more closely crowded. Because forms with large prolocula have relatively more chambers between the reference points, and a small number between the proloculum and the first point, the chamber number ratio is large. Because the rate of increase in whorl height decreases in forms with small prolocula, the chamber number ratio is small.

If the change in proloculum radius were unaccompanied by change in whorl height ratio, the chamber number ratio would be inversely relational. In the specimens studied, however, the change in whorl height ratio overcomes the effect of change in proloculum radius and the relationship between

chamber number ratio and the proloculum radius is direct. The number of chambers *between the two reference points* increases with increase in proloculum radius. This is a natural consequence of the variation in whorl height at the 12 mm. reference point. The effect of this increase is so small, however, that it is almost completely outweighed by the primary variation in proloculum radius, being only apparent in the greater area of scatter and less well-defined concentration of specimens.

Attempts were made to test the assumption that the volumetric ratio between chambers is approximately constant in all specimens, and at all but abnormal and gerontic growth stages. The exact value of this ratio cannot be calculated from the data available because it is dependent on the third dimension which is not present in thin sections. An approximation can be obtained however by determining the areal ratio and cubing its square root, but such a value is

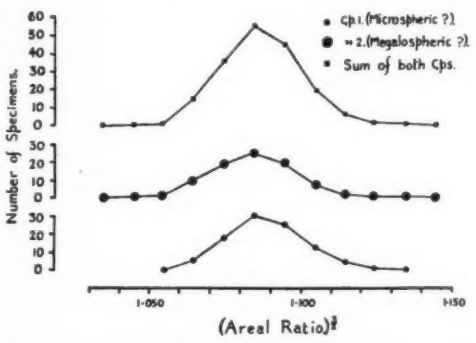


FIG. 8—Diagram showing variation in calculated volumetric ratios between adjacent chambers (cube of square root of areal ratio).

only an approach to the true volumetric ratio because of the multiplication of small errors. All chamber areas were measured on enlarged drawings of sections underlain by squared paper.

Variations in the value of the volumetric ratio are shown in figure 8. This quite evidently suggests that the volumetric ratio is not as constant as assumed. Consequently, the arguments outlined above may require modification.

The curves for both microspheric and megalospheric specimens show approximately symmetrical distributions about well-marked means. The range of variation in the significant portion of the curve of the microspheric form is slightly greater than that of the megalospheric form, but practically this difference is insignificant. Also, the values of

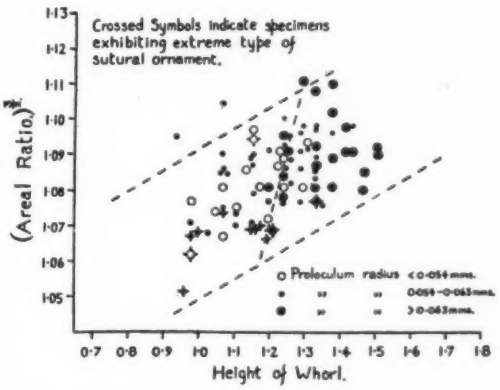


FIG. 9—Scatter diagram for megalospheric specimens of *Operculina complanata japonica* showing relationship between volumetric ratio, maximum internal proloculum radius and whorl height at point 12 mm. from proloculum measured around spiral.

the "highs" are closely similar. Therefore, the difference between the volumetric ratios of the two forms seems negligible.

In figure 9 volumetric ratios of the megalospheric specimens are plotted against whorl height at the 12 mm. reference point and three groups of proloculum radii are distinguished by symbols. To avoid confusion the distribution of microspheric specimens, which is identical in all respects, is not indicated.

The scattering in this diagram is remarkably uniform, if a few marginal specimens are disregarded, and there is no appreciable concentration of points in a central area or band. The pattern is nearly rhomboidal, with parallel long sides, and it is evenly bisected diagonally by the approximate boundary between the distributions of specimens with large and small prolocula.

Evidently the whorl height is directly relational to proloculum radius (see also fig. 3.) which is only slightly influenced by the volumetric ratio in an inverse manner. This is precisely the relationship expected if the previous reasoning is correct, because,

in specimens with the same whorl height and chamber number, the volumetric ratio must vary inversely with the proloculum radius. However, because the volumetric ratio variation is relatively small, it merely produces the slight thickening of the scatter evident in figure 3.

Similar plots of the number of chambers to the 12 mm. reference point, the chamber number ratio and the whorl height ratio against the volumetric ratio demonstrate inverse and direct subsidiary relations with the proloculum radius. For reasons similar to those given above these produce the thickenings of scatter seen in figures 4–6.

Internal structure of extreme forms.—No special attention has been directed to specimens with the two extreme types of ornamentation mentioned in the description of *O. complanata japonica*. They have, however, characteristic distributions in the scatter diagrams which indicates that the strength of ornamentation is related to the volumetric ratio. Microspheric specimens with high volumetric ratios are thin-shelled and delicately ornamented, megalospheric specimens with low volumetric ratios are thick-shelled and coarsely ornamented. Otherwise megalospheric specimens tend to be slightly more coarsely ornamented. The reason for this relationship is not clear but it may be a function of the metabolism of the living animal.

Repository.—The specimens that have been studied are deposited in the Micropaleontology Laboratory Collection, Geology Department, Imperial College of Science and Technology, London, England.

Catalogue numbers: *O. complanata japonica*, I.C.S.T. Micropal. 2001–2274; *O. bartschi ornata*, I.C.S.T. Micropal. 2300–2307; *O. ammonoides*, I.C.S.T. Micropal. 4000–4033; *A. quoyi*, I.C.S.T. Micropal. 2450–2480.

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JOURNAL OF PALEONTOLOGY, VOL. 27, NO. 2, PP. 251–256, PLS. 35–36, MARCH 1953

NEW PECULIAR FUSULINID GENUS FROM THE AKIYOSHI LIMESTONE OF SOUTHWESTERN JAPAN

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ABSTRACT—The new fusulinid genus *Akiyoshiella* is described from the Akiyoshi limestone of southwestern Japan with *A. ozawai*, n. sp., as the genotype. The structural features of *Akiyoshiella* and the associated fusulinids *Profusulinella* and *Staffella* suggest that *Akiyoshiella* is Moscovian (Pennsylvanian) in age.

INTRODUCTION

SINCE the late Dr. Y. Ozawa discovered the "liegende Falten" in the upper Paleozoic Chichibu System in the Akiyoshi limestone plateau in the Yamaguchi Prefecture of southwestern Japan in 1923, the limestone plateau and its environs has been an important area for modern biostratigraphic and geotectonic studies in Japan. Accordingly, after Ozawa (1925) published his famous paper (The stratigraphical and paleontological studies on the Chichibu System of Nagato) similar papers have been issued by many geologists and paleontologists in Japan. Ozawa's studies on fusulinid foraminifers of the Akiyoshi limestone were excellent at that time and have played a large part in biostratigraphic studies on the upper Paleozoic formations in Japan. It seems timely, however, that a restudy of the numerous fusulinid faunas of the Akiyoshi limestone be made in the light of other and more recently studied faunas.

I have surveyed the area and collected numerous fusulinids from the Akiyoshi limestone and from many limestone lenses in the noncalcareous facies developed around the Akiyoshi limestone. In the meantime, I have had an opportunity to visit the United States of America and to study both my collections and those of Ozawa with Professor M. L. Thompson of the Universty of Wisconsin. During these preliminary phases of the investigation, a new and unusual fusulinid genus was isolated.

ACKNOWLEDGEMENTS

I wish to express my most sincere gratitude to Professor M. L. Thompson of the University of Wisconsin who gave me kind criticism on this study and read over the manuscript; to Professor Teiichi Kobayashi of the Tokyo University who permitted me to restudy Ozawa's valuable collection, and to Professor Tatsuro Matsumoto, Professor Hisachi Matsushite, and my other colleagues in the Department of Geology, Kyushu University, for their advice and encouragement.

The expenses for this research were defrayed through the Scientific Research funds given by the Department of Education of the Japanese Government and through the Research Committee of the University of Wisconsin from funds furnished by the Wisconsin Alumni Research Foundation. Travel expenses from Japan to the United States were provided by the Military Government Association, Japan Chapter. My sincere thanks to these agencies for their good will and friendship.

All of the illustrated specimens of species described in this paper will be deposited in the Paleontological Repository of the Department of Geology, Kyushu University, and the catalogue numbers will be designated GKD-PT. Some topotype specimens will be kept in the Paleontological Collection of the University of Wisconsin.

SYSTEMATIC DESCRIPTION

Genus AKIYOSHIELLA, new genus

Genotype.—*Akiyoshiella ozawai* Toriyama, new species

Diagnosis.—The shell is small and bimorphic. The first three to five volutions are elongate fusiform, having narrowly rounded to more or less pointed poles and straight to somewhat curving axis of coiling. Shells of this stage composed of four or five volu-

tions have form ratios ranging from 2 0 to 3.1. The outer part of the shell is irregularly uncoiled, forming an aberrant flange which might be developed at the one side of the shell. The volume of the uncoiled part is almost twice or more that of the coiled one. The proloculus is spherical, sometimes ellipsoidal in shape, having a structureless dense layer. During the coiled stage of the shell, the chambers increase in height rather slowly in the first two volutions but more rapidly in the following two or three volutions. In some specimens the last volution of the coiled stage is more tightly coiled than the penultimate one.

The spirotheca is thin and seems to be composed of a thin opaque layer, the tectum, and a transparent layer, the diaphanotheca. In some parts of some specimens, however, the diaphanotheca cannot be observed, probably because of poor preservation or recrystallization after fossilization. Both upper and lower tectoria are sometimes present, and usually are not discernible in the last volution of the planispiral stage, showing that they are secondary deposits.

The tunnel is singular in the coiled part of the shell, but has not been recognized in the uncoiled flange. Chomata are developed in the first two or three volutions of the coiled part but seem to be absent in the outer volutions of the coiled part and in the uncoiled part of the shell. The septa are strongly fluted throughout the length of the shell in the coiled stage, and the intense fluting seems to be at the base of the septa so as to form inverted U's on the surface of the preceding volution. The septa are irregularly and strongly fluted in the uncoiled part of the shell. There is no axial filling in the shell.

Discussion.—This genus is the most distinctly aberrant of the Moscovian or Pennsylvanian fusulinids. There is no form to compare with it in the shell shape. As far as the developing of the flaring uncoiled gerontic stage is concerned, *Akiyoshiella* resembles *Codonofusiella* from the Upper Permian and *Nipponitella* from the Lower Permian, but these genera resemble one another in few other respects. The structure of their spirothecae, the shape of the coiled stage of their shells, the fluting of their septa, and their stratigraphic horizons are quite different.

It is not impossible to regard such abnormal features of the present materials as seen in the specimens 351-1 and 351-4g (plate 35, figs. 7 and 4) as deformation after fossilization. If such is the case, many more deformed specimens should be contained in other limestones of the Akiyoshi group. However, almost all of the Akiyoshi specimens seem to be in rather good state of preservation and show no evidence of having been deformed. I have been unable to obtain deformed specimens from any other part of the whole limestone mass. Moreover, one may consider that they might have been deformed accidentally. It is, however, unlikely that almost all deformed specimens should be found in only three localities. There is no evidence of deformation of other fusulinids in the limestone strata in which the genotype is contained or in the limestone beds lying immediately above or below them. I prefer to consider that the aberrant feature of the present genus is not due to deformation.

On the other hand, the limestone mass in which the present materials are contained seems to be conglomeratic, containing round or angular water-worn small fragments of bryozoans, corals, and limestone. However, almost all of the limestones in the Akiyoshi limestone group are more or less conglomeratic, if we call such features "conglomeratic." As Ozawa (1922) discussed in some detail, we may regard these limestone conglomerates as contemporaneous and as having accumulated in some special circum-

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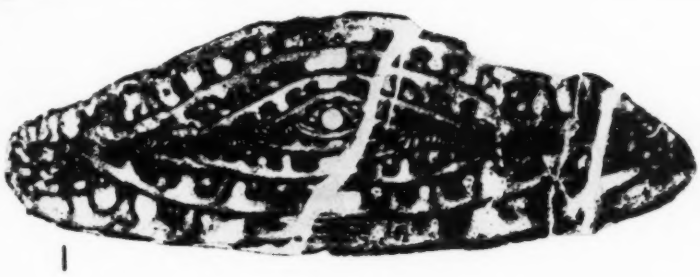
EXPLANATION OF PLATE 35

FIGS. *1–9*—*Akiyoshiella ozawai* Toriyama, n. sp. *1*, axial section of the holotype, ×20, 352-6a; *2*, axial section, ×20, 311-1a; *3*, axial section, ×20, 311-3; *4*, sagittal section showing the aberrant outer flange, ×20, 351-4g; *5*, sagittal section (slightly diagonal), ×20, 352-1a; *6*, sagittal section, ×20, 352-2a; *7*, tangential (?) section of the aberrant outer flange, ×20, 351-1; *8*, enlargement of a part of *5* showing the structure of the spirotheca, ×200, 352-1a; *9*, enlargement of a part of the holotype showing the structure of the spirotheca, ×200, 352-6a. (p. 253)



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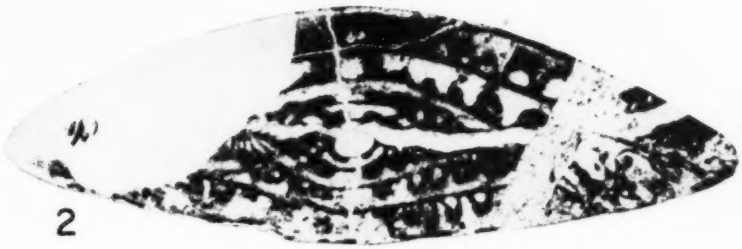

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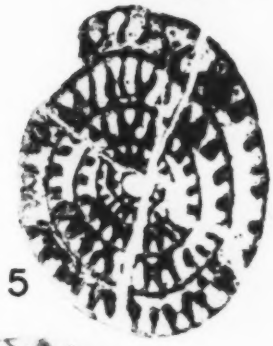

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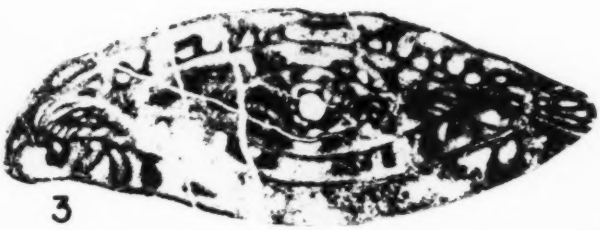

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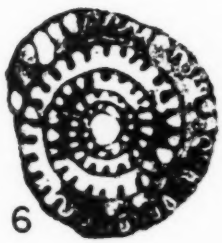

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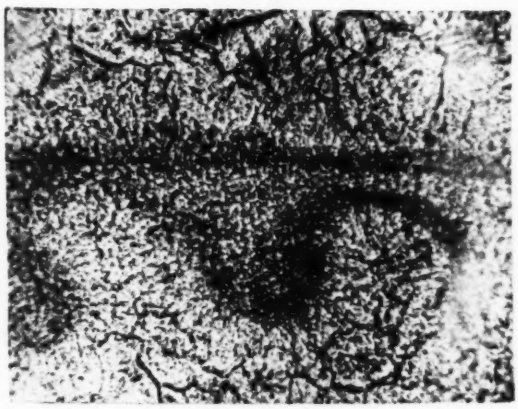

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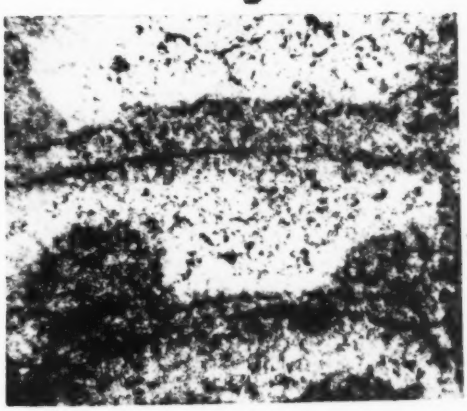

Toriyama, New Japanese Fusulinid

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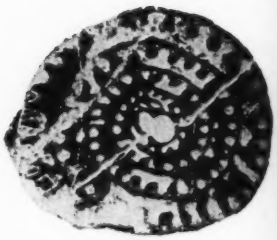

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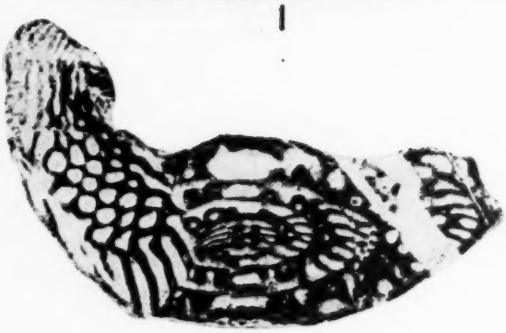

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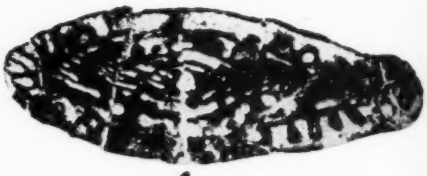

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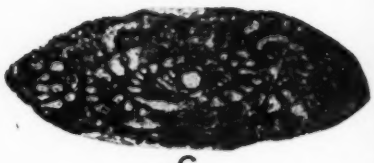

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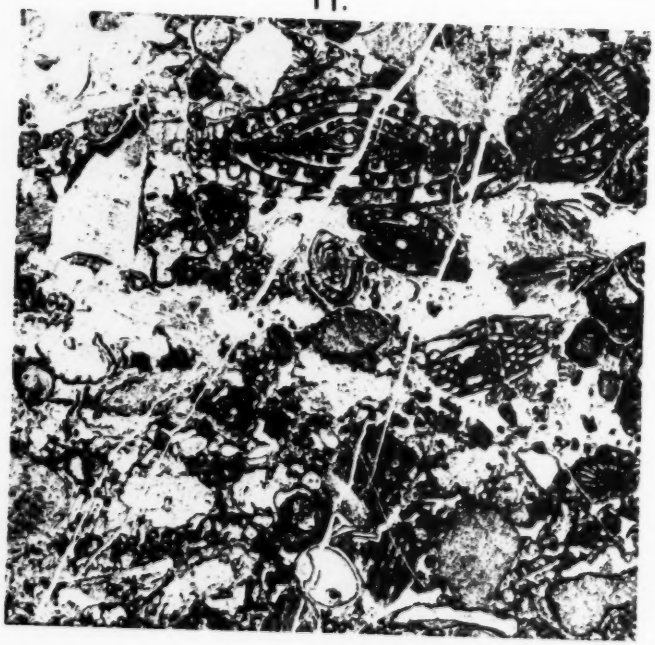

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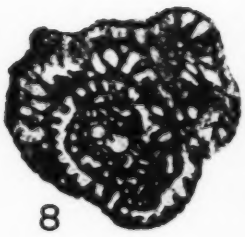

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Toriyama, New Japanese Fusulinid

stance of sedimentation. I consider that the type species of *Akiyoshiella* and other associated fusulinids are of the same age.

The phylogenetic relation of *Akiyoshiella* to other genera is not definitely known. As far as the spirothecal structure and intense septal fluting are concerned, it seems to have close relation to the genus *Fusulina*. There is no important difference of generic criteria between them, except that the last volution of *Akiyoshiella* becomes uncoiled as in the genera *Nipponitella* or *Codonofusiella*. On the other hand, the phylogenetic relation between *Fusulina* and *Fusulinella* has been fully discussed by many authors, and there is no doubt that the former was derived from the latter. It seems most probable that the genus *Akiyoshiella* is an aberrant offshoot of *Fusulinella*.

Age.—The genotype species came from the lower part of the Akiyoshi limestone group, associated with *Profusulinella* sp. and *Staffella*, n. sp. It was considered to be Moscovian in age by Ozawa, and is here considered to be Moscovian or Middle Pennsylvanian in age.

AKIYOSHIELLA OZAWAI Toriyama, new species

Plate 35, figs. 1–9; plate 36, figs. 1–3, 11

The shell of *Akiyoshiella ozawai* Toriyama, n. sp., is small and bimorphic; the early stage, consisting of three to five volutions, is elongate fusiform in shape; with narrowly rounded to pointed poles, a length ranging from 2.5 to 4.9 mm., and a width ranging from 0.9 to 1.7 mm.; giving form ratios of 2.1 to 3.1. Averages of the ratios of half length to radius vector for the first to fifth volutions of eight specimens are 2.2, 2.2, 2.6, 2.5, and 2.6, respectively. The lateral slopes are slightly convex to almost straight. The axis of coiling is straight or slightly curving.

The proloculus is spherical to sometimes ellipsoidal in shape and is rather large. It has an outside diameter of 0.142 to 0.306 mm., averaging 0.199 mm. in 30 specimens. The first two volutions are rather tightly coiled. In the following one or two volutions the chambers increase in height more rapidly, but they decrease again in the last volution of the coiled stage. The shell suddenly uncoils at maturity and forms a broad and irregular terminal flange of 2.5 mm. in height and 4 mm. in width, which might be developed only at one side of shell so as to envelop about one-half of the shell. The averages of the radius vector of the first to the fifth volution in 30 specimens are 0.17, 0.29, 0.45, 0.65 and 0.81 mm., respectively.

The spirotheca is thin and is composed of a tectum, diaphanotheca, and upper and lower tectoria. Both tectoria are not present in some parts of the shell and usually cannot be observed in the last volution of the coiled stage, although they are present in the spirotheca of the uncoiled flange. The averages of the tectum plus the diaphanotheca in the first to fifth volutions of 27 specimens are 0.014, 0.016, 0.019, 0.020, and 0.021 mm., respectively.

The septa are intensely and somewhat regularly fluted. The intense fluting of the septa seems to be at the base of the septa, for they make in axial sections a series of inverted U's on the surface of the outer tectorium of the preceding volution. Many septal loops appear in tangential sections which cut the shell near the base of the septa, but the septa almost parallel one another in sections cut near the tops of septa. In the uncoiled flange of the shell, septa seem

EXPLANATION OF PLATE 36

FIGS. *1–3*—*Akiyoshiella ozawai* Toriyama, n. sp. *1*, tangential section, ×20, 351-3c; *2*, tangential section, ×20, 352-3b; *3*, sagittal section, ×20, 311-4b. (p. 253)

4–8—*Akiyoshiella* sp. A. *4*, axial section (slightly diagonal), ×20, 451-1f; *5*, tangential section, ×20, 311-2c_2; *6*, axial section (more or less diagonal), ×20, 351-2a; *7*, sagittal section, ×20, 351-1c; *8*, sagittal section showing the growth of the outer flange, ×20, 352-1d. (p. 255)

9—*Profusulinella* sp., in the same section in which the holotype of *Akiyoshiella ozawai* Toriyama, n. sp., is found, ×20, 352-6e.

10—*Staffella* n. sp., from the same locality from which *4* was collected, ×20, 351-1e.

11—*Akiyoshiella ozawai* Toriyama, n. sp., thin section showing the texture of the limestone from Loc. 352, ×10. (p. 253)

to be intensely fluted. Averages of the septal count of the first to fourth volutions of six specimens are 9, 17, 24, and 30, respectively.

The width of the tunnel increases uniformly, and its path is almost straight in the coiled part of the shell. Averages of the tunnel angles for the first to fourth volutions of seven specimens are 27, 30, 35, and 34 degrees, respectively. Chomata are present in the first two volutions of the coiled part of the shell, but are indistinct or absent in the outer volutions. There are no axial fillings in the shell.

Discussion.—*Akiyoshiella ozawai*, n. sp., may be conspecific with *Schellwienia staffi* Ozawa, 1925, described from the same locality from which the present species was collected. Through the courtesy of Professor Kobayashi of the Tokyo University I have studied Ozawa's collection and compared it with mine. Unfortunately, however, I have not been able to find the original specimen of "*Schellwienia staffi*" in his collection. His description was very short and incomplete, but his illustration of the axial section (Ozawa's plate 4, fig. 1) is almost exactly the same as those of the present species, though the latter is slightly longer. Ozawa stated, however, that *S. staffi* has a very minute alveolar structure in the spiral wall. The fine alveolar structure which Ozawa considered to be present in his specimens may be due to some secondary structure caused by recrystallization after fossilization. No alveolar structure can be observed in the present specimens, even under the high magnification of the microscope.

No species is comparable to the present one except as mentioned above. *Akiyoshiella ozawai*, n. sp., is a peculiar fusulinid.

Pertinent quantitative data concerning *Akiyoshiella ozawai* is presented in Table I.

Occurrence.—*Akiyoshiella ozawai*, n. sp., is known from three localities, Loc. 311, Loc. 351, and Loc. 352. Loc. 351 and Loc. 352 are on the western slope of Shishidedai,

TABLE I.—MEASUREMENTS (in millimeters) OF *Akiyoshiella ozawai* TORIYAMA, n. sp.

Specimen	L.	W.	Form Ratio	Half Length					Ratio of H.l./R.v.				
				1	2	3	4	5	1	2	3	4	5
352-6a	4.42	1.57	2.8	0.27	0.58	1.28	1.65	2.25	1.9	2.3	3.0	2.6	2.6
311-1a	4.85	1.55	3.1	0.31	0.63	—	—	2.4	1.6	2.1	—	—	2.7
311-3	3.95	1.40	2.7	—	0.60	1.32	1.85	2.1	—	2.2	3.2	2.9	2.5
Maximum			3.1	0.42	0.66	1.32	1.85	2.4	2.9	2.5	3.2	2.9	2.7
Minimum			2.1	0.27	0.53	0.75	1.23	2.1	1.6	2.0	1.5	2.0	2.5
Average			2.6	0.33	0.59	1.05	1.55	2.25	2.2	2.2	2.6	2.5	2.6

Specimen	Radius Vector						Thickness of Spirotheca					
	0	1	2	3	4	5	0	1	2	3	4	5
352-6a	0.087	0.14	0.25	0.43	0.64	0.88	0.015	—	0.017	0.017	0.019	0.021
311-1a	0.10	0.19	0.30	0.45	0.67	0.88	0.016	—	0.019	0.017	0.024	0.025?
311-3	0.104	0.18	0.27	0.42	0.62	0.84	0.015	0.016	0.017	0.020	0.020	—
352-1a	0.084	0.15	0.24	0.42	0.60	0.80	0.014	—	0.013	0.018	0.023	0.017
352-2a	0.117	0.21	0.33	0.50	0.73	—	0.019	0.016	0.016	0.021	0.019	—
351-4g	0.071	0.14	0.23	0.42	0.59	0.80	—	—	0.016	0.019	0.016?	—
Maximum	0.153	0.21	0.34	0.52	0.74	0.88	0.019	0.017	0.020	0.026	0.025	0.025
Minimum	0.071	0.13	0.24	0.35	0.52	0.74	0.012	0.011	0.013	0.015	0.013	0.017
Average	0.099	0.17	0.29	0.45	0.65	0.81	0.016	0.014	0.016	0.019	0.020	0.021

Specimen	Tunnel Angle				Septal Count			
	1	2	3	4	1	2	3	4
352-6a	20	26	29	37	—	—	—	—
311-1a	39	42	44	32	—	—	—	—
311-3	31	29	40	52	—	—	—	—
352-1a	—	—	—	—	—	—	—	—
352-2a	—	—	—	—	10	18	23	30
351-4g	—	—	—	—	7	15	22	—
Maximum	39	42	44	52	11	18	26	30
Minimum	20	26	29	21	7	15	22	30
Average	27	30	35	34	9	17	24	30

Akag-mura, and Loc. 311 is the highest point of the pass between Narutaki and Tanaiwa, Beppu-mura. Heights above the sea-level are: Loc. 311=325 m., Loc. 351=300 m., and Loc. 352=240 m., respectively. All are in Mine-gun, Yamaguchi Prefecture, Southwestern Japan.

form, I will not establish a species for them. They are described and illustrated here for the sake of completeness.

The shell seems to possess almost the same characteristics as *Akiyoshiella ozawai* described above, having two stages of growth—the younger planispiral shell and

TABLE II.—MEASUREMENT (in millimeters) OF *Akiyoshiella* sp. A.

Specimen	L.	W.	Form Ratio	Half Length					Ratio of H.l./R.v.				
				1	2	3	4	5	1	2	3	4	5
351-1f	2.83	1.00	2.8	0.35	0.47	0.75	1.15	1.65	2.8	2.3	2.3	3.2	3.1
351-2a	2.44	0.89	2.7	0.31	0.49	0.75	1.23	—	2.7	2.7	2.5	3.0	—
Maximum				0.49	0.69	1.18	1.53	—	3.1	3.0	3.4	3.2	—
Minimum				0.27	0.47	0.75	1.15	—	2.0	2.3	2.3	2.4	—
Average				0.37	0.54	0.88	1.28	—	2.7	2.6	2.6	2.9	—

Specimen	Radius Vector						Thickness of Spirotheca				
	0	1	2	3	4	5	0	1	2	3	4
351-1f	0.083	0.13	0.21	0.32	0.47	0.53	0.011	0.014	0.014	0.018	0.021
351-2a	0.076	0.12	0.18	0.30	0.41	—	0.018	0.011	0.013	0.016	—
351-1c	0.086	0.13	0.23	0.36	0.56	—	0.012	0.011	0.013	0.014	0.016
352-1d	0.083	0.17	0.28	0.41	—	—	—	—	—	—	—
Maximum	0.102	0.17	0.28	0.41	0.57	—	0.018	0.014	0.017	0.019	0.022
Minimum	0.044	0.11	0.18	0.29	0.40	—	0.011	0.011	0.013	0.014	0.016
Average	0.073	0.13	0.22	0.35	0.50	—	0.015	0.013	0.014	0.017	0.020

Specimen	Tunnel Angle		Septal Count			
	2	3	1	2	3	4
351-1f	—	32	—	—	—	—
351-3d	25	38	—	—	—	—
351-1c	—	—	9	15	19	21
352-1c	—	—	9	17	22	28

Akiyoshiella ozawai occurs associated with *Akiyoshiella sp.* A, which will be described below, *Profusulinella* sp. and *Staffella*, n. sp. *Fusulinella biconica* and *F. itoi* occur in rocks (Loc. 353 and Loc. 354, 30 m. below Loc. 352) very near those from which the present species was collected. The present species undoubtedly is Middle Pennsylvanian or Moscovian in age.

AKIYOSHIELLA sp. A
Plate 36, figs. 4–8

Several sections of specimens of *Akiyoshiella* which differ slightly from the species described above were obtained from the same localities. As an insufficient number of well-oriented sections is available of this

the later flaring uncoiling part. The shell of the planispiral stage has an elongate fusiform shape with narrowly rounded to pointed extremities. The axis of coiling is almost straight. The lateral slopes are slightly convex to almost straight.

The proloculus is small, spherical, but ellipsoidal in shape in some specimens. Its outside diameter ranges from 0.088 mm. to 0.204 mm., averaging 0.146 mm. in thirteen specimens. The shell expands almost uniformly except for the first one or one and one-half volutions, which are tightly coiled. The averages of the radius vectors of the first to the fourth volution for thirteen specimens are 0.13, 0.22, 0.35, and 0.50 mm., respectively. The character of the uncoiled

part of the shell is not clearly known in my specimens, but it seems to be almost the same as in the preceding one.

The spirotheca is thin and is composed of a tectum, diaphanotheca, and upper and lower tectoria. The upper tectorium is not present in the last volution of the coiled stage. The averages of the combined thicknesses of the tectum and diaphanotheca in the first to the fourth volutions of 12 specimens are 0.013, 0.014, 0.017, and 0.020 mm., respectively. The septa are intensely fluted throughout the length of the shell, about the same as in *Akiyoshiella ozawai*. In the uncoiled part of the shell the septa seem to be fluted strongly and more or less irregularly. The tunnel widens its path somewhat irregularly. The chomata are indistinct even in the earliest volutions.

Discussion.—*Akiyoshiella* sp. A resembles *A. ozawai* in all important characters. However, the size of the shell and that of the proloculus are smaller than those of *A. ozawai*, its tunnel path is somewhat more irregular, and its chomata are not as distinct.

Pertinent quantative data concerning *Akiyoshiella* sp. A are presented in Table II.

Occurrence.—*Akiyoshiella* sp. A is associated with *A. ozawai* in all localities from which the former was collected, so the stratigraphic age is considered to be Middle Pennsylvanian or Moscovian.

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OSTRACODA FROM THE CAMDEN CHERT, WESTERN TENNESSEE

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ABSTRACT—The Camden chert (late Ulsterian) has yielded 38 species and varieties of Ostracoda, of which 29 are described in this paper. *Primitiella? nuculiforma*, *Strepulites swartzi*, *S. binodosus*, *Camdenidea camdenensis*, *Pachydomella thlipsuroidea*, *P. dorsoclefta*, and *Monoceratina cooperi* are new species; *Bollia ungulata depressa* and *B. ungulata bassleri* are new varieties. A new genus, *Camdenidea*, is tentatively assigned to the Cypridae.

Although the evidence is not conclusive, the ostracodes suggest that the Camden is early Onesquethaw in age. Ostracode species that occur in separate stratigraphic zones in the Onondaga of Pennsylvania appear to occur at the same horizon in the Camden.

Representatives of the Primitiidae have a weakly rabbeted hinge, have the muscle scar lying toward the narrower end of the shell, and lack inner lamellae. *Bollia*, representing the Drepanellidae, has either a simple valve contact along the hinge or has weak grooves and rabbet structures. Study of immature molts of *Bollia ungulata* suggests that its individuals passed through only about four molting stages. In the Thlipsuridae, *Thlipsura*, *Thlipsurella* and *Strepulites* probably lack calcified inner lamellae, but traces of them appear in *Stibus*. Inner lamellae are also present in *Ranapeltis* and *Camdenidea*. *Pachydomella*, besides the large normal canals, has numerous radial canals, one of the earliest occurrences of this shell character.

INTRODUCTION

THE Camden chert was named by Safford and Schuchert (1899) for exposures at Camden, Benton County, western Tennessee. It is presently classified by the Devonian subcommittee of the National Research Council's Committee on Stratigraphy as the early part of the Onesquethaw Stage, Ulsterian Series, Lower Devonian (Cooper, et al, 1942).

The lithologic sequence of Devonian rocks in western Tennessee was studied by Dunbar (1918), who revised the nomenclature from that previously in use. The sequence, summarized from Dunbar, but applying the time assignments of the Devonian subcommittee, is as follows:

DEVONIAN OR MISSISSIPPIAN SYSTEM

Chattanooga shale; black, fissile, carbonaceous shale about 20 feet thick, with thin basal sandstone (Hardin member).
Unconformity

DEVONIAN SYSTEM

Erian Series
Taghanic stage
Trousdale shale; proposed by Pohl (1930) for the lower part of what had been previously called Chattanooga shale in western Tennessee.
Unconformity
Tioughnioga stage
Pegram limestone (part)
Unconformity
Cazenovia stage (early part)
Pegram limestone (part), heavy-bedded white limestone, about 10 feet thick, represents main part of formation.
Ulsterian Series
Onesquethaw stage
Pegram limestone (?) (part)
Camden chert; thin-bedded, buff novaculite, 0–200 feet or more thick.
Deerpark stage
Harriman chert; heavier-bedded, white and buff novaculite, 30–55 feet thick.
Quall limestone; heavy-bedded, cherty, gray limestone, about 10 feet thick.
Unconformity
Helderberg stage
Decaturville chert; porous grey chert, about 6 feet thick.
Birdsong shale; blue, shaly limestone and shale, 35–65 feet thick.
Olive Hill formation; contains in descending order: the Flat Gap member of massive pure limestone, 0–53 feet thick; the Bear Branch and Pyburn members of oolitic-hematitic limestone and impure cherty limestone, respectively, 0–45 feet thick; and the Ross member of impure thin-bedded cherty limestone, 0–60 feet thick.

SILURIAN SYSTEM

Rockhouse shale; bluish-green, calcareous shale, 0–26 feet thick.

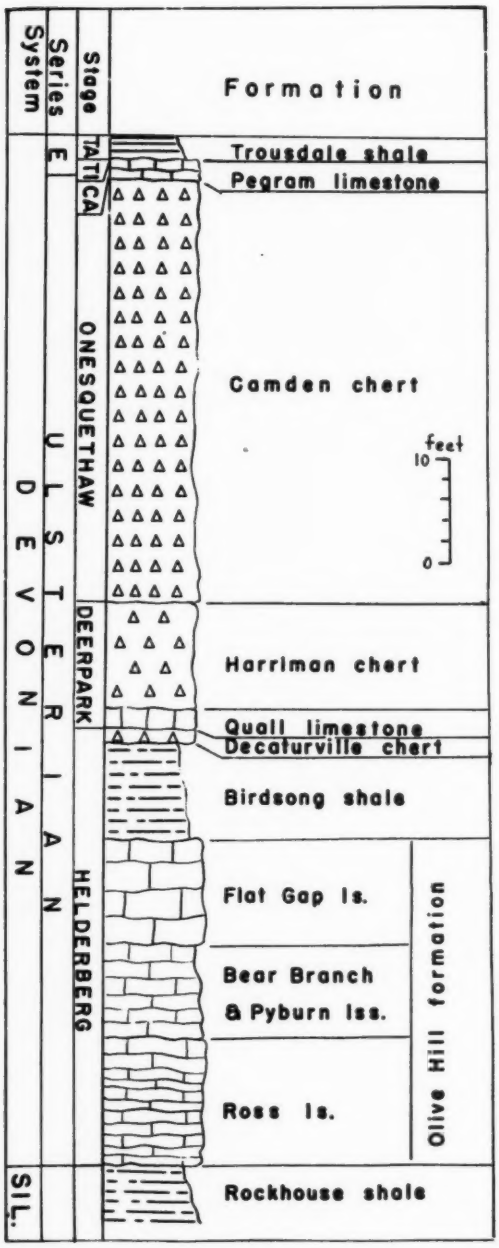


CHART 1.—Generalized columnar section of the Lower Devonian rocks in the vicinity of Camden, Tennessee (after Dunbar, 1918, and Cooper et al, 1942).

Bassler (1941) described 27 species of Ostracoda from the Camden chert; 24 of the species and four of the genera were described as new. The three previously described species, *Bollia burgeneri* Swartz, *B. sagittaformis* Swartz and *Thlipsurella secoclefta* Swartz all occur in the Shriver chert of Pennsylvania. Bassler's *Bollia sagittaformis* is here referred to *B. planojugosa* Swartz and Swain of the Onondaga formation of Pennsylvania.

The ostracode material described by Bassler was obtained—"from clay beds resulting from the decomposition of chert layers near base of the Camden formation at the quarry half a mile south of Camden, Tenn. Collections at this point were made by Professor Schuchert for the National Museum many years ago, then by the writer [Bassler] later, and finally in more abundance by Dr. G. A. Cooper and R. D. Mesler in recent years" (Bassler, 1941, p. 22).

The ostracodes that form the basis for the present paper according to Dr. G. A. Cooper (written communication), "came from a quarry opposite the railroad station in Camden, Tennessee. No definite horizon can be stated for the specimens because they came from pure white clay found on the floor of the quarry. They evidently came from somewhere in the quarry wall, but I never located any of the material in place."

In the present paper 29 species and varieties are described and illustrated. Seven of the species and two of the varieties are new and one new name is proposed. The purpose of the study was to describe the species that were not considered by Bassler in 1941, and to reconsider several of his generic and specific assignments. Ten of Bassler's species were not found in the present collection and are not included in this paper. The species dealt with herein are:

FAMILY PRIMITIIDAE Ulrich and Bassler, 1923
- Genus PRIMITIELLA Ulrich, 1894
  - P. cf. P. inornata (Ulrich), 1890
  - P.? nuculiforma Swain, n. sp.

Family DREPANELLIDAE Swartz, 1936
- Genus BOLLIA Jones and Holl, 1886
  - B. planojugosa Swartz and Swain, 1941
  - B. ungulata Bassler, 1941
  - B. ungulata depressa Swain, n. var.

B. ungulata bassleri Swain, n. var.
B. tribolbina Bassler, 1941
B. obesoides Bassler, 1941
Family QUASILLITIDAE Coryell and Malkin, 1936
Genus GRAPHIODACTYLUS Roth, 1929
G. sp. aff. G. lineatus (Ulrich and Bassler)
G.? sp.
Family KIRKBYIDAE Ulrich and Bassler, 1906
Genus AMPHISSITES Girty, 1910
A. lunatus Bassler, 1941
Family THLIPSURIDAE Jones, ?
Genus STREPULITES Coryell and Malkin, 1936
S. swartzi Swain, n. sp.
S. typicus (Bassler), 1941
S. bispinosus (Bassler), 1941
S. clavatulus (Bassler), 1941
S. bifurcatus (Bassler), 1941
Genus STIBUS Swartz and Swain, 1941
S. binodosus Swain, n. sp.
Genus THLIPSURA Jones and Holl, 1869
T. furcoides Bassler, 1941
Genus THLIPSURELLA Swartz, 1932
T. secoclefta Swartz, 1932
Family THLIPSURIDAE or Family KLOEDENELLIDAE Ulrich and Bassler, 1906
Genus THLIPSURINA Bassler, 1941
T. elongata Bassler, 1941
T. simplex Bassler, 1941 (see Healdia camdenensis Swain, new name)
T. similis Bassler, 1941 (=T. elongata)
Family HEALDIIDAE Harlton, 1933
Genus HEALDIA Roundy, 1926
H. camdenensis Swain, new name
Family BAIRDIIDAE Sars, 1887, or Family CYPRIDAE Baird, 1846
Genus CAMDENIDEA Swain, n. gen.
C. camdenensis Swain, n. sp.
Family uncertain
Genus RANAPELTIS Bassler, 1941
R. typicalis Bassler, 1941
R. unicarinata Bassler, 1941
Genus PACHYDOMELLA Ulrich, 1891
P. thlipsuroidea Swain, n. sp.
P. dorsoclefta Swain, n. sp.
P. multitubulis (Swartz and Swain), 1941
Genus MONOCERATINA Roth, 1928
M. cooperi Swain, n. sp.

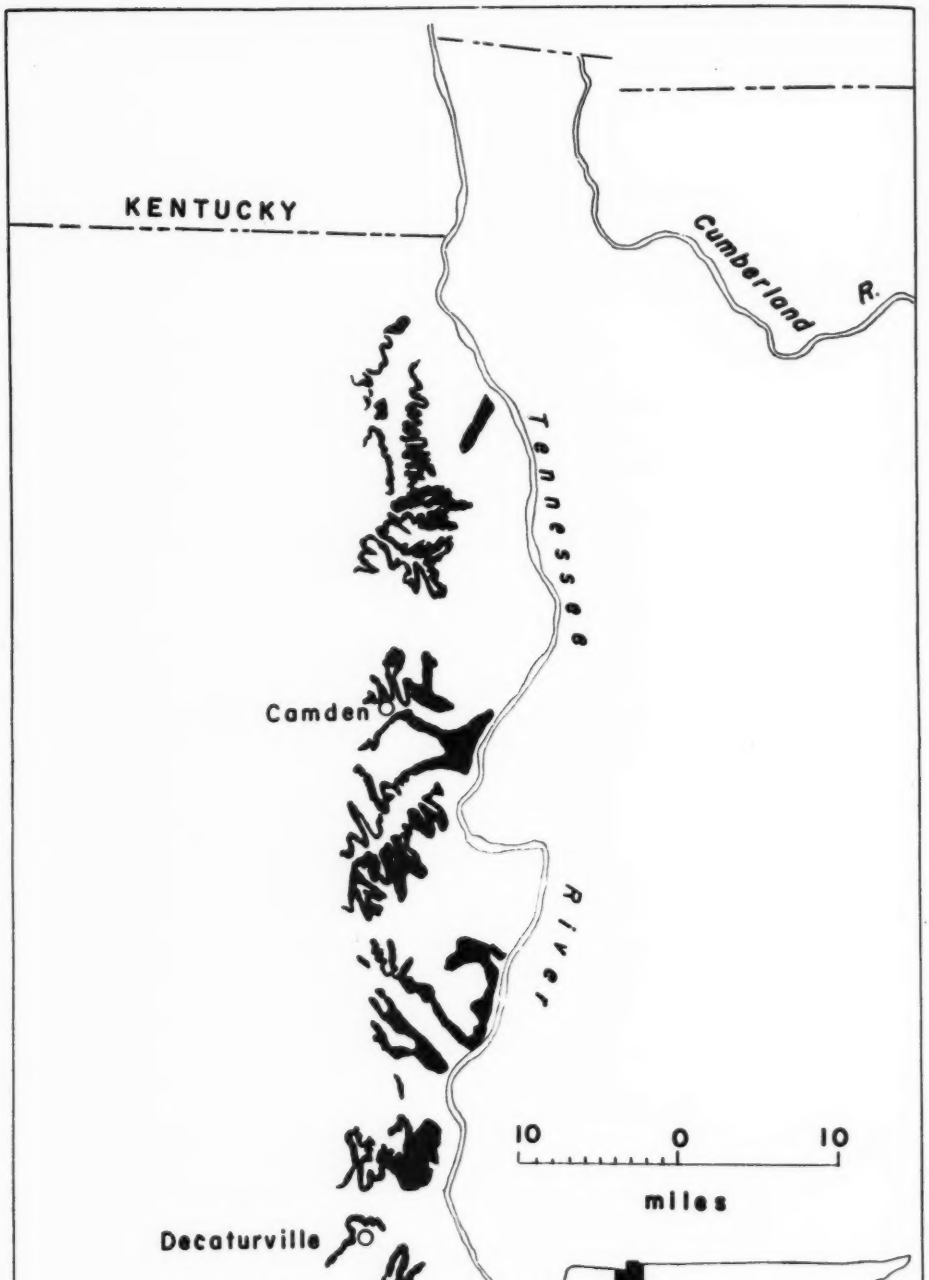
Age relationships of the fauna.—On the basis of brachiopods Cooper et al (1942, pp. 1748, 1780) correlate the Camden chert with the Schoharie grit, as the latter is developed in the southern Hudson Valley district of New York. The Camden is therefore considered to be in part slightly older than the Onondaga limestone of New York and entirely older than the shaly facies of the Onondaga in central Pennsylvania, eastern West Virginia and western Maryland.

Table I lists species of Camden Ostracoda that have been found in other formations. These eight species represent 21 per cent of the 38 ostracode species that have been identified from the Camden. Only three species or seven per cent of the fauna are found in rocks other than the Onesquethaw stage, and these indicate an earlier Devonian age. Of the six Onesquethaw species, three can be assigned a fairly definite stratigraphic position, and suggest middle to lower Onondaga. Therefore, the rather sparse indications of age, at hand, suggest that the Camden chert represents the earlier portion rather than the later portion of the Onesquethaw stage.

While studying these ostracodes the writer became impressed that in this single lot are species that occur in stratigraphically separate positions in the shaly facies of the Onondaga formation of Pennsylvania. Because of uncertainty as to the precise stratigraphic occurrence of the Camden ostracodes, it is not now possible to determine: (1) whether there has been a convergence of the zones of the shaly Onondaga, (2) a mingling of these species due to environmental causes, or (3) whether actual zonal distribution in the Camden has been concealed by the way in which the collections were made.

Of the 10 Camden species described by Bassler that are not included in this paper, only one, *Amphissites ulrichi* Bassler, was found in the present sample, and only two specimens of that species were seen. It is not known whether Bassler's collection represents the same stratigraphic position as the present collection, or a different one.

Preservation of the specimens.—All of these ostracodes have undergone silicification. In most instances the preservation is evidently excellent so far as surface ornamental features are concerned, with tiny



MAP I.—Distribution of Devonian rocks in western Tennessee from Geologic Map of Tennessee, 1933. The ostracodes described in this paper came from the type locality of the Camden chert.

spines and reticulations well displayed. Some of the specimens assigned to *Graphiodactylus* Roth developed Beekite rings during silicification, but none of the other species shows this feature. Internal features, other than hingement and gross marginal structures, perhaps have been partly lost during silicification. The trace of the original calcified portion of the inner lamellae is visible in some instances, obscure in others. The position of the muscle scar is shown in many specimens by a small node, spot, or lucid area, but small details of the scars are mostly lacking.

Silicified bryozoans and brachiopods also occur with the ostracodes.

Acknowledgements.—Appreciation for their assistance in arranging for loan of the Camden ostracodes is expressed to Dr. R. S. Bassler and Dr. G. A. Cooper of the U. S. National Museum. John C. Kraft assisted in the study of *Bollia ungulata* Bassler. A University of Minnesota Graduate School summer research appointment and research grant-in-aid 276-3201-2100 supported the writer in this study.

Depository of specimens.—All type specimens are deposited in the U. S. National Museum (U.S.N.M.).

TABLE I.—CAMDEN OSTRACODA THAT OCCUR IN OTHER FORMATIONS

Species	Series	Stage	Formation	Locality
?Camdenidea camdenensis Swain, n. gen., n. sp.	Ulsterian	Helderberg	Haragan marl	Northeastern Oklahoma
Bollia burgeneri Swartz	Ulsterian	Deerpark	Shriver chert	Central Pennsylvania
Thlipsurella secoclefta Swartz	Ulsterian	Deerpark	Shriver chert	Central Pennsylvania
Pachydomella multitubulis (Swartz and Swain)	Ulsterian?	Onesquethaw	Lower Onondaga formation (*Ranapeltis trilateralis* zone)	Central Pennsylvania
Ranapeltis unicarinata Bassler	Ulsterian?	Onesquethaw	Lower Onondaga formation (*Bollia ungula* zone)	Central Pennsylvania
Bollia planojugosa Swartz and Swain	Ulsterian?	Onesquethaw	Middle Onondaga formation (*Bollia platyloba, Bollia planojugosa* zone)	Central Pennsylvania Eastern West Virginia
?Thlipsura furcoides Bassler	Ulsterian?	Onesquethaw	Onondaga formation undifferentiated	Central Pennsylvania
Primitiella cf. *P. inornata* (Ulrich)	Ulsterian?	Onesquethaw	Jeffersonville limestone	Northern Kentucky

SYSTEMATIC DESCRIPTIONS

Family PRIMITIIDAE Ulrich and Bassler, 1923

The Primitiidae represent the simplest and most primitive ostracodes of the Beyrichiacea and were defined by Ulrich and Bassler (1923, p. 297) as, "relatively simple Beyrichiacea with undefined to well-defined median sulcus or simple median pit."

Bassler and Kellett (1934, pp. 16–25) referred ostracodes having the aforementioned characteristics to a subfamily, the Primitiinae, and expanded the concept of the family to include as a second subfamily, the frilled eurychilinid ostracodes.

Swartz (1936, p. 549) removed the eurychilinids from the Primitiidae and defined the family as follows:

"Small, straight-backed, unisulcate Ostracoda; frequently subrhomboidal, with the cardinal angles distinctly unequal; surface occasionally with inconspicuous swellings near the sulcus, and in part with inconspicu-

ous rim or false border along the free edges, but never with strongly developed knobs, marginal ridge or marginal frill. Hingement essentially simple, at least so far as known. Overlap wanting or inconspicuous; sexual dimorphism unknown."

The hinge surface in two typical primitiids, *Primitiella* Ulrich and *Milleratia* Swartz, can be observed in well-preserved, pyritized specimens in the writer's collections from the depauperate zone, basal Maquoketa of northeastern Iowa. The hinge is weakly rabbeted. The muscle scar in the same two genera consists of a small protuberance containing several obscure spots, and situated on the inner transverse ridge that represents the external median sulcus. The muscle scar lies near the more narrowly rounded anterior end of the shell, and following the concept that in living ostracodes the muscle scar tends to be anterad of midlength, the narrower end of the primitiids is believed to be anterior.

Inner lamellae are lacking in *Primitiella* and *Milleratia*, but the marginal portion of the valve interior is smoother than the rest of the interior surface, suggesting some kind of differentiation of the marginal portion of the animal.

Levinson (1951) has showed that there is retention of earlier instar valves on the exterior surface during growth in two primitiid genera, *Eridoconcha* Ulrich and Bassler and *Cryptophyllum* Levinson. This phenomenon probably is more widespread than has been realized; Swain and Peterson (1951) observed it in a Jurassic ostracode, and the specimens of *Milleratia* from the Ordovician of Iowa mentioned above, also show retention of instar valves.

Genus PRIMITIELLA Ulrich, 1894

"Carapace usually oblong, equivalved, moderately convex; surface smooth or finely punctate; in the dorsal slope a broad, shallow and quite undefined depression represents an undeveloped mesial sulcus" (Ulrich, 1894, p. 647).

The internal structures of the genus are described above. Ulrich remarked in his original diagnosis that *Youngia* Jones and Kirkby [= *Youngiella* Jones and Kirkby] of the Carboniferous differed from *Primitiella* primarily in the crenulate hinge of the former, and suggested an ancestral relationship between the two.

Type species.—*Primitiella constricta* Ulrich.

Geologic range.—Ordovician to Devonian.

PRIMITIELLA cf. P. INORNATA (Ulrich)

Plate 37, figs. 1a–d; text fig. 1

Aparchites inornatus ULRICH, 1891, Jour. Cincinnati Soc. Nat. Hist., p. 46, pl. 16, figs. 3a,b.

Shell subovate in lateral view, highest about one-third from posterior end; dorsal

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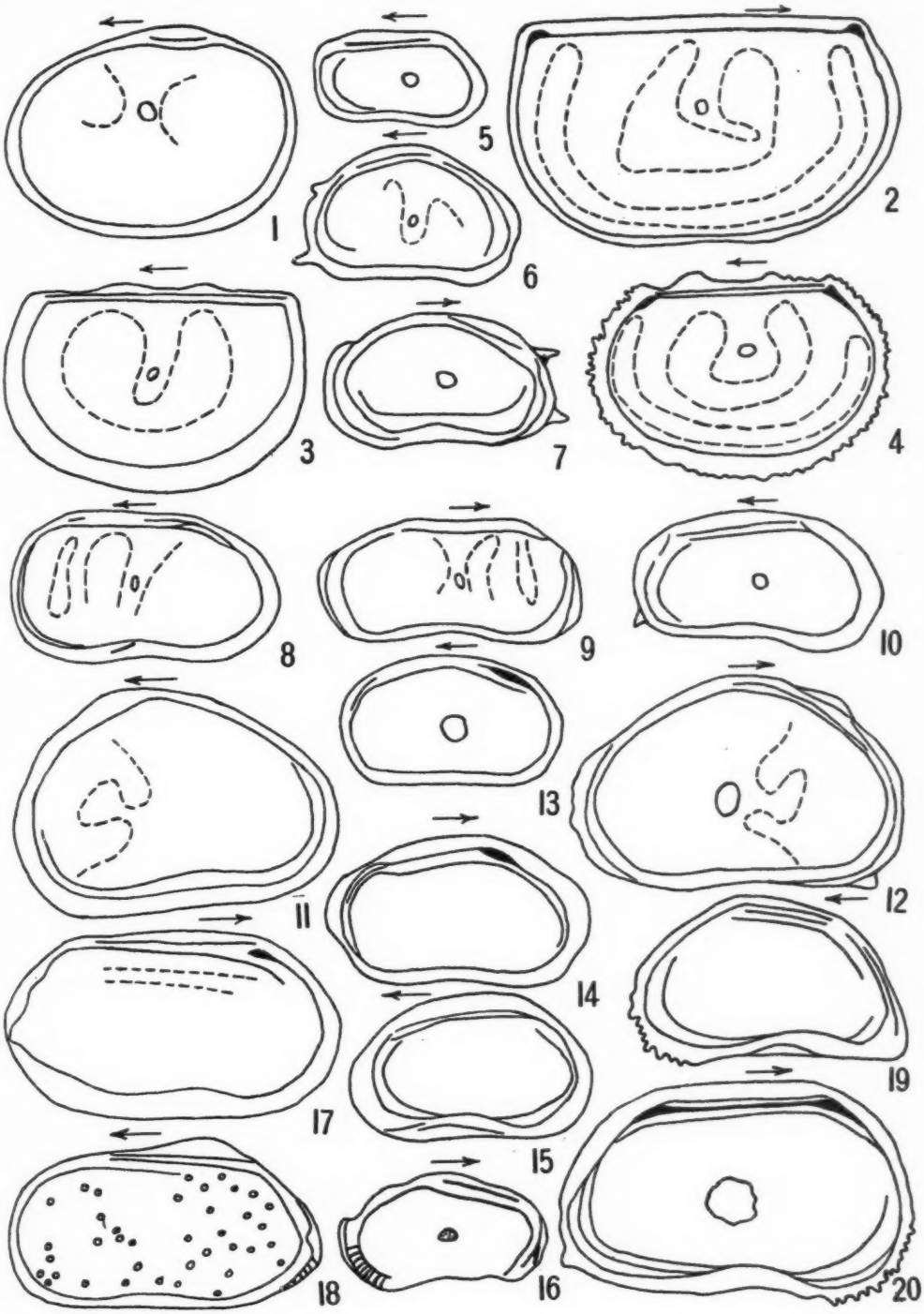
EXPLANATION OF TEXT FIGS. 1–20

The arrows point toward the anterior end of the valve.

FIG. *1*—*Primitiellia* cf. *P. inornata* Ulrich. Right valve interior; ×30. USNM 118042 b. (p. 262)
2—*Bollia planojugosa* Swartz and Swain. Left valve interior; ×33. USNM 118045 a. (p. 265)
3—*Bollia ungulata* Bassler. Right valve interior showing slightly incised line along hinge; ×30. USNM 118046 d. (p. 266)
4—*Bollia obesoides* Bassler. Right valve interior; ×30. USNM 118050 a. (p. 268)
5—*Strepulites clavatulus* (Bassler). Right valve interior; ×30. USNM 118063 a. (p. 274)
6—*Thlipsurella secoclefta* Swartz. Right valve interior; ×33. USNM 118055. (p. 275)
7—*Strepulites bispinosus* (Bassler). Left valve interior; ×30. USNM 118061 c. (p. 273)
8, 9—*Thlipsurina elongata* Bassler. Right and left valve interiors; ×33. USNM 118053 c, d, respectively. (p. 276)
10—*Strepulites bifurcatus* (Bassler). Right valve interior; ×30. USNM 118062 b. (p. 274)
11, 12—*Thlipsura furcoides* Bassler. Right and left valve interiors; ×34. USNM 118054 c, b, respectively. (p. 275)
13, 14—*Healdia camdenensis* (Bassler) Swain, new name. Right and left valve interiors; ×33. USNM 118073 e, d, respectively. (p. 278)
15, 16—*Strepulites swartzi* Swain, n. sp. Right and left valve interiors; ×30. USNM 118057 b, c, respectively. (p. 272)
17, 18—*Pachydomella dorsoclefta* Swain, n. sp. Left and right valve interiors; ×35. USNM 118072 a, b, respectively. (p. 281)
19, 20—*Ranapeltis typicalis* Bassler. *19*, interior of a small right valve; *20*, left valve interior; ×33. USNM 118075 a, c, respectively. (p. 279)



TEXT FIGS. 1–20

margin nearly straight and about two-thirds of shell length; ventral margin strongly convex, converging anteriorly with respect to dorsum; terminal margins rounded, the anterior narrower but forming a more obtuse cardinal angle than the posterior. Complete examples not seen but valves apparently are about equal in size without appreciable overlap except along hinge. Convexity of valves moderate, greatest thickness about one-third from posterior end.

Postdorsal corner of each valve slightly flattened; an obscure concentric incision runs from dorsal margin near postcardinal angle to median or anteromedian part of shell. In left valve is a small weak anteromedian pit, dorsad of which lies an obscure subvertical sulcus; corresponding features scarcely developed or lacking in right valve. General surface smooth.

Hinge edge of right valve extended below and channeled above for reception of the extended and barlike hinge edge of right. Inner lamellae lacking. Muscle scar an anteromedian small protuberance marked by several tiny spots and situated on a low ridge that extends diagonally from dorsum toward anteroventral region; the protuberance and ridge represented on exterior surface by the pit and sulcus; anterad of ridge is a rounded pit where shell wall is very thin and can be seen as a pellucid spot on the exterior in some specimens; it may represent the position of the eye.

Length of right valve (plate 37, fig. 1a), 1.09 mm.; height, 0.79 mm.

Remarks.—In general shape and obscure external sulcus and pit in the left valve, as well as the general absence of these features in the right, the present species can be placed with reservation in *Primitiella* Ulrich (1894, p. 647). *Primitiella inornata* (Ulrich) (1890, p. 46) from the Jeffersonville limestone at the Falls of the Ohio, Louisville, Kentucky, resembles the present specimens very much, although Ulrich emphasizes a flattening of the ventral margin fore and aft of the position of greatest ventral extension that is not apparent in the present specimens.

Types.—Figured specimens U.S.N.M. 118042 a–d.

PRIMITIELLA? NUCULIFORMA Swain, n. sp.
Plate 37, figs. 2 a,b

Shell subquadrate in side view; highest near anterior end; hinge margin slightly sinuous, about two-thirds of shell length with anterior cardinal angle broadly obtuse, posterior angle much less obtuse; ventral margin gently convex, flattened medially in right valve; anterior margin rounded, slightly extended below; posterior margin broader, truncate in dorsal half. Left valve probably, but not certainly, larger than right. Valves moderately convex, postdorsal third of shell strongly swollen and near posterior cardinal angle extends slightly beyond dorsal margin. A narrow compressed border occurs along posterior margin. Postdorsal swollen area bears several large pits; surface otherwise smooth.

Hinge surface of right valve consists of terminal obscure, elongate elevations that fit into corresponding shallow depressions in left valve; intervening portion of hinge surface consisting of simple contact of valves. Inner lamellae lacking. Muscle scar obscured by matrix.

Length of left valve (holotype), 0.50 mm.; height, 0.38 mm.

Relationships.—The generic relationships of this form are obscure, but the outline, hingement and flattening of the posterior border are suggestive of *Primitiella* Ulrich. The interiors of both valves are filled with matrix so that musculature and possible submedian vertical internal ridge cannot be seen. The hingement apparently separates the species from *Aparchites* Jones although the general form and postdorsal slight umbonation are reminiscent of that genus. *Burlella* Coryell and Booth is of similar form and is swollen terminally, but bears an additional ventroterminal swelling. "*Bythocypris*" *subquadrata* Stewart (1936, p. 755) from the Silica shale of Ohio has a similar shape, but is more pointed posteriorly in edge view, has a slightly concave ventrum and a smooth surface.

Types.—Holotype U.S.N.M. 118043, paratype U.S.N.M. 118044.

Family DREPANELLIDAE Swartz, 1936

"Subquadrate to subovate Ostracoda with long straight hinge, and subequal, generally well defined cardinal angles;

usually with a strong ridge paralleling all or part of the free margins; primitively with swellings near the dorsomedian sulcus, the swellings sometimes forming two or more strong knobs, which may connect ventrally to form a U-shaped ridge, or may become obsolete. Hingement apparently simple; marginal overlap wanting or inconspicuous" (Swartz, 1936, p. 552).

Genus BOLLIA Jones and Holl, 1886

"Distinguished by a centrally situated looplike or horseshoe-shaped ridge, the free upper extremities of which are often bulbous; a more or less complete marginal ridge may be present or wanting." (Bassler and Kellett, 1934, p. 17).

Type.—*Bollia uniflexa* Jones and Holl.

Geologic range.—Ordovician-Devonian.

The hingement of the species of *Bollia* Jones and Holl studied here consists either of the simple undifferentiated valve edges, or of weak grooves or rabbet-joint structures. The muscle scar occurs on the inner ridge that represents the external median sulcus; it consists of a small protuberance or a rounded spot containing obscure markings. It is nearly at midlength and consequently is of little value in orienting the shell. The orientation here used considers the bulbous portion of the inner ridge to be anterior, following the concept of Swartz (1936, p. 574).

Inner lamellae are lacking in the genus.

Remarks.—Swartz (1936, p. 573), in his study of *Bollia* from the Lower Devonian Shriver chert of Pennsylvania, noted that the Shriver species fall into three distinct sections: (1) forms in which the marginal ridge is strong and extends along the free margin from dorsal angle to dorsal angle, the inner ridge is enlarged but flattened at least at one of its ends, and the surface is pitted, represented by *B. sagittaformis* Swartz and *B. burgeneri* Swartz; (2) forms in which the marginal ridge is moderately well-developed, the ends of the inner ridge are expanded as elevated knobs, and the surface is papillate, represented by *B. americana zygocornis* Swartz; and (3) forms in which the marginal ridge is low, the inner ridge lacks expanded ends, and the surface is smooth, characterized by *B. cristata* Swartz and *B. ungula* Jones.

Three similar sections of *Bollia* were observed by Swartz and Swain (1941) in the Onondaga formation of Pennsylvania: (1) *B. planojugosa* Swartz and Swain is similar in main elements of the shell to *B. sagittaformis* Swartz; (2) *B. diceratina* Swartz and Swain resembles *B. americana zygocornis;* and (3) *B. platyloba* Swartz and Swain belongs in the section of *B. ungula* Jones, the former occurring in a zone above that which contains *B. ungula* in the Onondaga.

In the present single collection all three sections are represented: *B. planojugosa* Swartz and Swain represents the first group; *B. obesoides* Bassler belongs in the *B. zygocornis* group; and *B. ungulata* Bassler, *B. ungulata* var *depressa*, n. var., *B. ungulata* var. *bassleri*, n. var., and *B. tribolbina* Bassler are related to *B. ungula*.

BOLLIA PLANOJUGOSA Swartz and Swain, 1941

Plate 37, figs. 3a–g; text fig. 2

Bollia sagittaformis Swartz, BASSLER, 1941, Jour. Washington Acad. Sci., vol. 31, p. 23, fig. 11 (not Swartz, 1936).

?Bollia burgeneri Swartz, BASSLER, 1941, ibid., fig. 10 (not Swartz, 1936).

Bollia planojugosa SWARTZ and SWAIN, 1941, Bull. Geol. Soc. Am., vol. 52, p. 423, pl. 4, figs. 1a–g.

Bollia spinomuralis SWARTZ and SWAIN, 1941, ibid., pp. 423–424, pl. 4, figs. 2a–c.

A detailed description of the external features of the shell was provided in the original description. The bulbous portion of the inner ridge is considered to be anterior in position. An important characteristic not clearly seen previously is the keel-like nature of the marginal ridge along the terminal margins where it projects distinctly beyond the marginal slopes. The outer margin of the shell in terminal regions is somewhat flared, resulting in formation of a shallow groove between outer margin and marginal ridge. The ventral surface essentially lacks this groove and marginal zone along ventrum is nearly perpendicular to plane of commissure.

Along hinge, valve edges are in simple contact; in some specimens, several weak striations occur along hinge surface and there are weak cardinal notches. Along free margins, valve edges apparently are in direct opposition without overlap; weak striations present along marginal zone in

some specimens. Inner lamellae entirely lacking. Muscle scar occurs almost exactly at midlength on inner median swelling which is represented on exterior of valve by median sulcus. Scar consists of a small nodelike elevation and, although appearing more coarsely granular than adjoining shell in transmitted light, is evidently without distinct minor elements.

Length of left valve (plate 37, fig. 3c), 1.63 mm.; height, 0.94 mm.

Remarks.—This species differs from *B. sagittaformis* Swartz, of the Lower Devonian Shriver chert, in the greater width of the postventral portion of the U-shaped inner ridge, and the somewhat greater width of the entire ridge. These small differences were not evident to Bassler (1941) when he studied the Camden chert ostracodes, so that he referred the Camden examples to *B. sagittaformis*. Several of the immature molts in the present collection lack the broadening of the inner ridge and are indistinguishable from *B. sagittaformis*. *B. spinomuralis* Swartz and Swain apparently represents an early molt of *B. planojugosa*. One of the present forms (plate 37, fig. 3a) has the posterior portion of the inner ridge slightly swollen like that in *B. burgeneri* Swartz, and this type appears to have been that identified as *B. burgeneri* by Bassler (1941, p. 23, fig. 10).

Types.—Figured specimens U.S.N.M. 118045a–e.

Occurrence.—This species has been found elsewhere in the Shriver chert, Deerpark stage, and in the Onondaga formation, Onesquethaw stage, in Pennsylvania (Swartz, 1936, Swartz and Swain, 1941).

BOLLIA UNGULATA Bassler

Plate 37, figs. 4a–g, 5a,b; text fig. 3

?Bollia ungula JONES (part), 1889, Am. Geol., vol. 4, p. 338, figs. 12 a,b.
Bollia ungulata BASSLER, 1941, Jour. Washington Acad. Sci., vol. 31, p. 23, fig. 5.

Shell subquadrate in side view; hinge margin nearly straight, about nine-tenths of shell length, with well-defined cardinal angles, of which the anterior is slightly the more obtuse. Greatest height slightly posterior to midlength. Ventral margin gently convex, merging with uniform curvature into ends; terminal margins broadly rounded, anterior slightly extended medially. Valves apparently equal in size.

Free margin in each valve bears a narrow, low rim that slightly overhangs outer margin terminally, but forms a flattened marginal zone along ventrum, perpendicular to plane of contact of valves. Inner U-shaped ridge much higher than marginal ridge; its anterior portion broadened to form an elongate bulbous expansion; posterior limb of ridge bears a knife-edged crest along its outer margin; in some specimens, crest continues around ventral portion of ridge. General surface in well-preserved specimens finely and weakly reticulate.

Inner lamellae narrow, occurring in narrow ventral and terminal flattened zone, edge of lamellae fused to shell wall along both inner and outer margins.

Hingement simple; right valve bears a weak groove dorsad of narrowed and slightly extended hinge-edge; edge of left valve apparently slightly overlaps right along hinge. Muscle scar consists of a small protuberance located on surface of inner swelling that represents the external median sulcus.

Length of right valve (plate 37, fig. 4a), 1.34 mm.; height, 0.90 mm.; convexity of valve, 0.47 mm.

Remarks.—This species was described by Bassler (1941, p. 23) as differing from the Onondaga species *Bollia ungula* Jones, "in the shorter, higher valves with a more pronounced bulb occupying the anterior limb of the inner ridge." *B. ungulata*, in its well-defined crest along the posterior limb of the inner ridge is close to *B. platyloba* Swartz and Swain (1941, p. 419) also of the Onondaga formation of Pennsylvania. This species, although somewhat resembling *B. sagittaformis* and *B. planojugosa* in the bulbous anterior portion of the inner ridge, differs strongly from them in the lesser height of the marginal ridge.

Types.—Figured specimens U.S.N.M. 118046 a–g.

Molt stages in B. ungulata.—The length-height ratios of about 200 specimens of *B. ungulata* are shown graphically in figure 21. The measurements were made by John C. Kraft. The data indicate that this species is characterized by only four instars rather than eight, the number believed to occur in living marine ostracodes, or nine, the number of molt stages believed to occur in living freshwater ostracodes (Sohn, 1950, p. 428; Hoff, 1942, p. 35). Paleontologists have tended to assume eight or nine molt stages

in fossil ostracodes (Scott, 1951a, 1951b) although Sohn (1950, p. 428) has raised several objections to this practice.

Although only four instars are suggested by the measurements made on specimens of *B. ungulata*, several unknown factors make this conclusion subject to uncertainty: (1) study of insufficient number of specimens, (2) incomplete preservation involving, in this case, both original calcification of instar valves and subsequent silicification, (3) mixing of specimens from different horizons in which the mean values from different horizons varies markedly. Item 4 is not a factor here because dimorphism is not known to occur in this group of species. The importance of item 5 can not be evaluated here because of lack of knowledge as to what sieving of the material had been done before the collection reached the writer's hands. There are many particles in the washed residues that are smaller than about 0.45 mm., the length of the smallest instar valve, but these may have broken out of larger pieces subsequent to the washing.

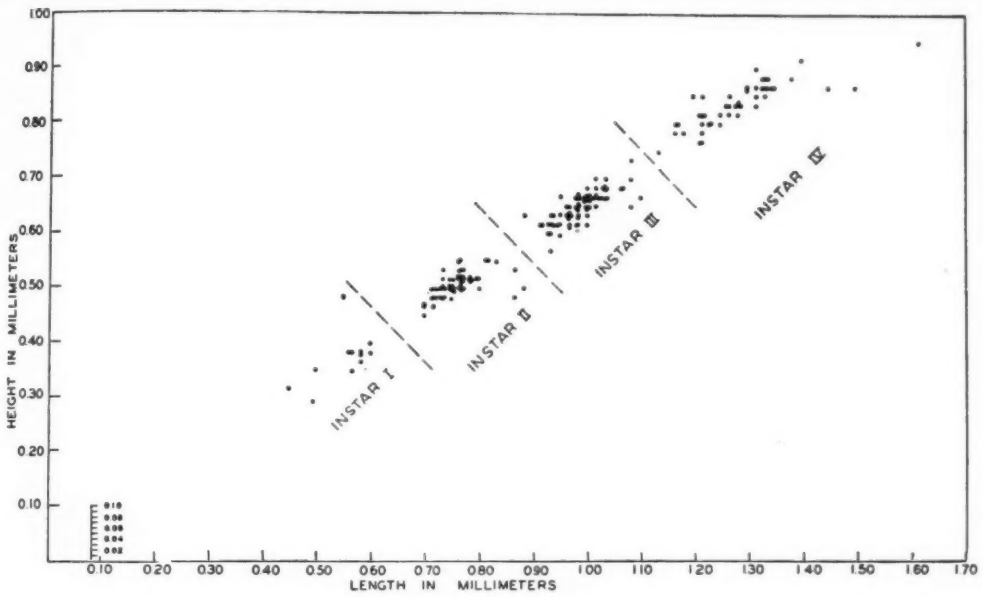


FIG. 21—Length-height ratio in *Bollia ungulata* Bassler.

of dimensions of the various instars might differ because of environmental factors, (4) dimorphism, and (5) loss of smaller specimens in collecting and preparing the sample. Item 1 is not believed to be a hampering factor because at least six percent of the specimens are in the lowest arbitrary size group in which fewer specimens are to be expected because of fragility. Item 2 probably has operated to produce smaller numbers of recoverable molts in the earliest instar; otherwise the matter of survival would result in decreasing numbers of instars in each growth stage. Item 3 can not be judged because of insufficient information on the stratigraphic position of the collection, but in other instances the optimum size of adult ostracodes of the same species

Despite all these uncertainties, the writer believes that *B. ungulata* molted only four or five times, with the realization that more careful analysis will be required to prove the assertion. The influence of the environment on the ontogeny of fossil ostracodes has not been given enough consideration. With regard to the affect of the alteration of the optimum food supply on larval development of insects, the work of Mickel and Standish (1946) on *Tribolium confusum*, a flour beetle, is of interest. It was found that when the diet of the larvae of this beetle was changed from wheat flour, the normal food, to soybean flour, the length of the larval period (16 days) was increased as much as three times at 25°C. and as much as six times at 35°C. Along

with this prolongation of larval development there was a corresponding increase in the number of instars from the normal figure of six to as many as 18.

One can visualize the complexity attached to the analysis of ostracode molts collected from as little as six inches of sedimentary rock representing diverse environmental conditions.

BOLLIA UNGULATA var. BASSLERI
Swain, n. var.
Plate 37, figs. 6a–e

This variety differs from *B. ungulata* Bassler in having the dorsal end of the posterior limb of the inner U-shaped ridge strongly elevated to form a blunt rounded node, and having a prominent transverse furrow across the ridge ventrad of the node-like extension. Other shell characteristics as in *B. ungulata*.

Length of holotype, a right valve (plate 37, fig. 6a), 1.18 mm.; height, 0.80 mm.; convexity of valve, 0.50 mm.

Types.—Holotype U.S.N.M. 118047 a, paratypes U.S.N.M. 118047 b–d.

BOLLIA UNGULATA var. DEPRESSA
Swain, n. var.
Plate 37, figs. 8a–f

Differs from *B. ungulata* Bassler in the relatively greater width of the inner U-shaped ridge, and the marked depression of the inner portion of the posterior limb of this ridge. The general surface apparently is weakly pitted, rather than reticulate as in *B. ungulata*.

Length of holotype, a right valve, 1.17 mm.; height, 0.71 mm.; convexity of valve, 0.44 mm.

Types.—Holotype U.S.N.M. 118049 a, paratypes U.S.N.M. 118049 b–e.

BOLLIA TRIBOLBINA Bassler
Plate 37, figs. 7a–e

Bollia tribolbina BASSLER, 1941, Jour. Washington Acad. Sci., vol. 31, p. 23, figs. 6, 7.

Shell small, subquadrate, elongate; hinge margin nearly straight and nine-tenths of shell length with well-defined cardinal angles, the anterior the more obtuse; ventral margin nearly straight to slightly convex and subparallel to dorsum; anterior margin slightly convex, somewhat extended below midheight, truncate above; posterior margin truncated, making nearly a right angle with dorsum. Valves apparently equal in size.

Free margins of each valve bear a relatively low but distinct, narrow, marginal rim that strongly overhangs outer margin; surface of ridge rounded anteriorly, angulated along its outer border posteriorly. Inner ridge consists of an anterior, large, bulbous expansion, a narrow ventral portion, and a broad posterior portion, the middle of which is strongly depressed. Median sulcus narrow, strongly curved forward in its ventral part. General surface in well-preserved specimens weakly and finely reticulate.

Hingement simple, without ridges or grooves and apparently without overlap. Muscle scar a small protuberance on internal swollen expression of the median sulcus. Narrow inner lamellae present along ventrum, completely fused to internal primary wall along both inner and outer margins.

Length of figured right valve (plate 37, fig. 7a), 0.91 mm.; height, 0.52 mm.; convexity of valve, 0.30 mm.

Remarks.—This unusual species of *Bollia* is closely related to *B. ungulata* Bassler in its surface reticulation, low marginal rim, and more strongly elevated inner ridge with prominent bulbous expansion. The more elongate shell and particularly the strong depression of the midportions of the posterior limb of the inner ridge necessitate recognizing it as a distinct species rather than a variety of *B. ungulata*.

Types.—Figured specimens U.S.N.M. 118048 a–c.

BOLLIA OBESOIDES Bassler
Plate 37, figs. 9a–e; plate 38, figs. 1a–d; text fig. 4

Bollia obesoides BASSLER, 1941, Jour. Washington Acad. Sci., vol. 31, p. 23, figs. 8, 9.

Shell subquadrate to subovate in lateral view; highest medially to slightly postmedially; hinge margin nearly straight to somewhat sinuous, about three-fourths of shell length; cardinal angles distinctly obtuse; ventral margin convex, passing uniformly into broadly rounded terminal margins; dorsal slopes of terminal margin truncate. Valves probably about equal in size although complete carapaces were not observed. Convexity of valves rather low.

A broad rounded rim occupies free margins of each valve. Slightly above mid-

height, surface of marginal rim tends to drop abruptly toward cardinal angle; in some specimens a nodelike swelling occurs at this position, but in other specimens the decline of the surface is quite gradual; these variable conditions may occur at either or both ends. A narrow furrow borders inner margin of rim and separates it from the broad U-shaped inner ridge; rounded knobs occur dorsally, at ends of inner ridge; anterior knob larger and elongated toward ventrum, posterior edge of knob expanded to define the short forward-bending dorsomedian sulcus. A low, but variable swelling occurs on postventral broadened portion of inner ridge. General surface of valves varies from nearly smooth to partly or completely set with closely spaced papillae. In some specimens, including both adult and immature valves, the node-crests, ventral portion of inner ridge, and the marginal rim may bear scattered pustules or short spines.

In both valves hinge face bears a narrow groove running its entire length, and there are terminal weak notches visible in right valve. Free margin of right valve bears a narrow selvage groove for reception of edge of left. Inner lamellae narrow, fused to shell wall along both inner and outer margins. Muscle scar consists of a large rounded spot containing many small obscure markings; it is located on an inner swelling that represents the external median sulcus.

Length of right valve (plate 37, fig. 9a; plate 38, fig. 1c), 1.19 mm.; height, 0.84 mm.; convexity of valve, 0.47 mm.

Remarks.—This species is of uncertain status and may eventually be referred to *Bollia americana* Ulrich and Bassler (1913, p. 525) from the Shriver chert of Maryland and Pennsylvania; at present the writer is not sufficiently familiar with that species to make an adequate comparison.

B. obesoides belongs to the general group of *Bollia hindei-B. zygocornis*. The distinguishing features of several American species of this group are as follows (the "knobs" represent the swollen terminal portions of the inner marginal ridge):

1. *Bollia americana* Ulrich and Bassler; knobs lack conical protuberances, surface papillate, original figure shows small knobs on terminal portions of marginal rim, but Swartz (1936, p. 575) describes this feature only at the anterior end. [Shriver chert (Oriskany), Maryland, Pennsylvania]

2. *Bollia americana* var. *zygocornis* Swartz; like preceding but with small knob on posteroventral portion of inner ridge. [Shriver chert (Oriskany), Pennsylvania]

3. *Bollia obesoides* Bassler; knobs without protuberances, surface papillate to spinose, low swellings may occur midterminally on marginal rim or postventrally on inner ridge. [Camden chert (Onondaga), Tennessee]

4. *Bollia diceratina* Swartz and Swain; both knobs with conical protuberances, surface papillate. [Shaly facies of Onondaga formation, Pennsylvania, West Virginia]

5. *Bollia diceratina* var. *fimbriata* Swartz and Swain; spines or pustules on anteroventral part of marginal ridge. [Shaly facies of Onondaga formation, Pennsylvania]

6. *Bollia obesa* Ulrich; knobs without protuberances, surface smooth. [Jeffersonville limestone (Onondaga), Kentucky]

7. *Bollia hindei* Jones; conical protuberance on posterior knob, surface strongly papillate. [Hamilton, undifferentiated, New York]

8. *Bollia widderensis* Coryell and Malkin; more elongate than *B. hindei*, possibly a dimorph of that species according to Warthin (1937, card 41). [Widder beds (Hamilton), Ontario].

Types.—Figured specimens U.S.N.M. 118050 a–e, 118052 a–c.

Family QUASILLITIDAE Coryell and Malkin, 1936

Graphiodactylidae KELLETT, 1936, Jour. Paleontology, vol. 10, p. 772.

Genus GRAPHIODACTYLUS Roth, 1929

Graphiadactyllis ROTH, 1929, Wagner Free Inst. Sci. Publ. No. 1, p. 10.

Graphiodactylus ROTH, 1929, Jour. Paleontology, vol. 3, pp. 292, 293.

Bassleria HARLTON, 1929, Am. Jour. Sci., ser. 5, vol. 18, p. 255.

Paracythere ULRICH and BASSLER, 1932, Tenn. Div. Geol., Bull. 38, pl. 27, figs. 4, 13.

Barychilina Ulrich (part), ULRICH and BASSLER, 1932, Tenn. Div. Geol., Bull. 38, pl. 27, figs. 2, 3.

There is considerable confusion attendant upon the various species that have been assigned to *Graphiodactylus* Roth and *Quasillites* Coryell and Malkin. *Bassleria* Harlton and *Paracythere* Ulrich and Bassler were placed in synonymy with *Graphiodactylus* by Kellett (1936, p. 723) who also introduced the family Graphiodactylidae with *Graphiodactylus* as its only genus.

The present writer's understanding of *Graphiodactylus* is as follows:

Shell subquadrate in side view; hinge margin long and nearly straight in right valve, nearly straight to somewhat convex in left; ventral margin nearly straight to slightly concave, subparallel to dorsum or converging slightly toward posterior with respect to dorsum; anterior margin rounded, most extended medially to ventromedially, subtruncate above; posterior margin typically more narrowly rounded, most extended dorsad of midheight. Left valve larger than right, extending beyond the other rather strongly along dorsum and ventrum, less strongly terminally. Valves moderately convex, thickest postmedially.

Free margins of right valve bear a narrow frill or flange that becomes very obscure or absent along dorsal half of anterior margin; along ventral half of anterior margin, frill is broadest and at midheight typically is produced as a small spine. In left valve, corresponding frill much weaker or absent, but some vestige of it generally occurs anteroventrally. General surface ornamented by delicate, narrow, bifurcating and anastomosing riblets that generally are oriented longitudinally in midportion and concentrically in outer portion. Some species are granulose, tuberculose or finely reticulate, and some bear a postventral submarginal spine. A smooth median spot represents position of muscle scar.

Hinge of right valve consists of an anterior slightly elongate, high, crenulate tooth, a posterior high, more rounded, crenulate tooth; the interterminal area consisting of the narrowed and strongly recessed valve edge, beveled and with a narrow groove on its under side, and at its ends separated from teeth by troughlike sockets. Hinge of left valve correspondingly consists of terminal sockets and an interterminal bar that is formed by the narrowed valve edge and is slightly overlapped by right valve; hinge line slightly incised with respect to dorsal surface of valve, so that in right valve view of a complete shell, dorsal margin of left valve extends beyond that of right. Inner lamellae narrow; line of concrescence and inner margin coincide. Muscle scar consists of a median, round pit bearing several small spots.

Type species.—*Kirkbya lindahli arkansana* Girty, Roth, 1929.

Geologic range.—Devonian to Pennsylvanian.

Remarks.—*Quasillites* Coryell and Malkin is only slightly different from *Graphiodactylus;* it has the posterior slope of the valve surfaces more steeply inclined, with an angular crest typically developed at the summit of the slope; and the left (larger) valve has its dorsal margin more convex than the right giving that valve a subovate outline (Swartz and Oriel, 1948, p. 555). The latter feature apparently occurs also in some species of *Graphiodactylus* so its generic value is questionable. According to Swartz and Oriel a ventroposterior spine occurs in all known species of *Quasillites;* similar spines are present in several species of *Graphiodactylus.*

On the basis of these similarities it might prove desirable to place *Quasillites* in synonymy with *Graphiodactylus.* If so then Graphiodactylidae Kellett, 1936, is the valid familial name. At present the Quasillitidae contains only *Quasillites* and *Graphiodactylus.*

GRAPHIODACTYLUS sp. aff. G. LINEATUS
(Ulrich and Bassler)
Plate 38, figs. 11a–e

Main features of the shell are as described for the genus. In the larger specimens at hand, the silicification has resulted in the formation of Beekite rings that in part obscures the shell features. Surface ornamentation consists of very fine concentric riblets in outer portion of shell, and of longitudinal riblets in median portion. A small submarginal spine or node occurs near postventral marginal bend. Illustrations of *G. lineatus* (Ulrich and Bassler) (1932, pl. 27) from the Ridgetop shale of Tennessee do not show the marginal frill and anterior spur. Additional material from the Ridgetop should be studied to determine whether *lineatus* belongs with *Graphiodactylus* or with *Barychilina* where Ulrich and Bassler originally placed it.

Length of left valve (plate 38, fig. 11b), 1.39 mm.; height, 0.83 mm.; convexity of valve, 0.36 mm.

Remarks.—Some species of *Quasillites* described by Swartz and Oriel (1948) from the Windom beds, Upper Devonian, of New York are similar in shape and presence of a postventral spine, but differ in detail of the ornamentation, and in the steeper

declivity of the posterior end.

Among other species of *Graphiodactylus*, *G. tenuis* Cooper from the Fayetteville shale of Arkansas apparently is a synonym of *G. cornuta* (Ulrich and Bassler) from the Ridgetop shale of Tennessee.

Types.—Figured specimens U.S.N.M. 118064 a–e.

GRAPHIODACTYLUS? sp.
Plate 39, figs. 1a,b

Shell elongate, subquadrate in lateral view; dorsal margin nearly straight, about three-fourths of shell length with poorly-defined cardinal angles, of which the anterior is the more obtuse; ventral margin nearly straight, slightly concave medially and subparallel to dorsum; terminal margins broadly rounded, the anterior slightly extended below, the posterior somewhat narrower and slightly extended above. Left valve larger than right, extending strongly beyond the other except postventrally. Valves moderately convex, thickest postmedially. Surface ornamented by narrow ridges that rise in dorsal region and trend obliquely in a postventral direction; scattered, fairly numerous pustules occur in more marginal portion of surface, and are scarce in median portion.

Hinge of right valve consists of terminal elongate toothlike elevations, the intervening hinge edge rather strongly recessed and beveled on its ventral slope. Terminal teeth pass ventrally into a prominent selvage ridge that borders free margins. Inner lamellae not observed to occur. Muscle scar situated in a rounded depression that lies anterad of midlength and is flanked posteriorly by a transverse, low broad ridge; scar consists of a small group of spots in bottom of depression but its details could not be seen.

Length of a right valve, 1.70 mm.; height, 0.94 mm.; convexity of valve, 0.51 mm. The surface of this specimen has been affected by silicification but its proportions apparently have not been changed.

Remarks.—This form probably belongs in *Graphiodactylus*, and is related to *G. granopunctata* (Ulrich and Bassler) but does not have preserved the narrow marginal flange that is characteristic of the genus. *G. granopunctata* lacks the oblique narrow surface ridges of the present species. Most of the specimens at hand are strongly affected by silicification, with development of Beekite rings.

Types.—Figured specimens U.S.N.M. 118067 a,b.

Family KIRKBYIDAE Ulrich and Bassler, 1923

"Valves straight-hinged, joined together by a ridge or teeth in the left fitting into corresponding sockets on the right, essentially equal but with edge of right valve fitting into the slightly rabbeted edge of the left, the left valve thus slightly overlapping the right. Surface reticulate with several nodes and a subventral pit or muscle spot." (Bassler and Kellett, 1934, p. 32.)

Remarks.—Kellett (1933, p. 83) stated that five genera of the Kirkbyidae form a natural unit characteristic of the family; *Kirkbya*, *Amphissites*, *Ulrichia*, *Mauryella*, and *Knightina* all are "closely related in the common possession of similar hinge and marginal structure, kirkbyan pit, reticulated surface, and homologous nodes." Bassler and Kellett, however, in 1934 (p. 17) included *Ulrichia* in the Primitiidae, and Swartz (1936, p. 533) placed it in the Drepanellidae.

It appears that the present status of the family was best summed up by Ulrich and Bassler (1923, p. 315) in their original definition of the family, which was, "A most variable and probably unnatural association of equivalved genera of Beyrichiacea tending toward the Cytheracea. Typically with a distinct false border and a subventral well-defined pit and often with concentric or transverse more or less parallel ridges."

Genus AMPHISSITES Girty, 1910

Subrectangular, ends blunt, cardinal angles obtuse, hinge line depressed; surface with a well-defined median node, and frequently with other nodes, typically pitted; an outer flange and sometimes an inner flange border free margins. Hinge consists of a groove in right valve for reception of thin edge of left, and with terminal left valve teeth and corresponding right valve sockets (after Kellett, 1933).

Type species.—*Amphissites rugosus* Girty.

Geologic range.—Devonian to Permian.

AMPHISSITES LUNATUS Bassler, 1941
Plate 39, figs. 2a-c

The external characteristics of the species have been provided by Bassler (1941,

p. 24). The observed features of the interior are as follows.

Hinge long and straight, consisting of simple contact of valve edges, except terminally, where there are short weak grooves in the right valve and corresponding ridge-like elevations in the left. A prominent slightly anteromedian node represents external pit and probably is the site of the muscle scar; anterad of node is a shallow depression. Inner lamellae not differentiated. Free margins apparently are in simple contact. Frill set well back from outer margin, broadest terminally and with strong transverse ridges on its under side.

Length of left valve (plate 39, figs. 2a,c), 1.25 mm.; height, 0.68 mm.; convexity of valve, 0.34 mm.

Types.—Figured specimens U.S.N.M. 118068 a,b.

Family THLIPSURIDAE Ulrich, 1894

"Reniform or ovate inequivalved shells less than 2 mm. in length, the margin of one valve overlapping that of the other more or less completely. Dorsal margin arcuate, ventral sometimes straight or even slightly sinuate; surface with two or more definite pits. Determination of right and left valve arbitrarily made." (Ulrich and Bassler, 1923, pp. 316, 317.)

Swartz (1932) presented a revision of several genera belonging in this family. Warthin (1945) introduced the subfamilies Thlipsurinae and Ropolonellinae and revised some of the genera.

The Thlipsuridae were placed by Ulrich and Bassler (1923, p. 316) in the superfamily Cypridacea, presumably because of the curved hinge margin and small size.

The Camden chert material provides information as to the internal structures of several genera of the family, as follows.

Thlipsura: hinge surfaces rabbeted; muscle scar anteromedian, consisting of a group of possibly radially arranged spots; selvage groove in right valve; inner lamellae lacking.

Thlipsurella: hinge margin rabbeted, located mostly in front of midlength; muscle scar median, composed of a compact group of about three spots on inner transverse swelling; selvage groove in right valve; inner lamellae lacking.

Stibus: hinge margin rabbeted, located mostly in front of midlength; muscle scar apparently a spot on internal median tubercle; terminal selvage grooves in right valve; inner lamellae present.

Strepulites: hinge in left valve has terminal low elevations and interterminal groove and ridge; right valve with converse features; muscle scar a slightly anteromedian elevated spot; selvage groove in larger right valve; inner lamellae apparently lacking.

Genus STREPULITES Coryell and Malkin, 1936

Octonariella BASSLER, 1941, Jour. Washington Acad. Sci., vol. 31, p. 27.

Valves reniform or subovate, unequal; right valve larger. Dorsal margin convex; ventral margin concave ventrally or straight; ends of valves rounded. Valves ornamented by narrow ridges somewhat paralleling the margins.

Type species.—*Strepulites mooki* Coryell and Malkin.

Geologic range.—Lower and Middle Devonian.

Remarks.—Several species that are generally similar to *Octonaria* Jones have been placed in *Strepulites* (see Warthin, 1945). The differences between these two genera are not now clear.

STREPULITES SWARTZI Swain, n. sp.
Plate 38, figs. 5a–d; text figs. 15,16

Shell subovate-elongate in lateral view; highest about one-fourth from posterior end; dorsal margin gently convex; ventral margin slightly concave; posterior margin broadly rounded, slightly extended a little venterad of midheight, truncate above; anterior margin slightly more narrowly rounded. Right valve larger than left, overlapping it and extending beyond its margin dorsally and ventrally. Valves moderately convex; greatest thickness anteromedian.

Marginal area of right valve smooth and compressed; left valve marginal area smooth but compressed only posteriorly. Median elevated surface of each valve bordered by a narrow ridge, that anteriorly is more strongly elevated and overhangs anterior slope. Two sinuous, longitudinal ridges occupy midportion of each valve, and converge posteriorly; about twelve transverse spurs are sent forth from flanks of longitudinal ridges, providing characteristic pitted appearance of valve surface.

Hinge of left valve consists of a posterior

elongate thickened elevation beginning at broadly obtuse cardinal angle, extending well down dorsal slope and terminating in a low node, a long straight interterminal groove bounded dorsally by a narrow ridge and an anterior, somewhat elongated, but shorter and more knoblike elevation lying at less obtuse anterocardinal angle. Hinge of right valve consists of an anterior oblique socket, an interterminal narrow bar, bounded dorsally by a groove, and a posterior elongate groove. Free margin of right valve bears a prominent selvage groove for reception of edge of left. Midventral margins of each valve bent inward, and that of right valve extended. Inner lamellae not clearly differentiated. Muscle scar not well understood, but apparently consists of a small rounded, in some instances slightly elevated, spot lying at midlength and venterad of midheight. Interior surface of valve dorsad of muscle scar slightly raised as a low transverse ridge or several low swellings. No pore canals were observed.

Length of holotype, a right valve (plate 38, fig. 5a), 1.07 mm.; height, 0.63 mm.; convexity of valve, 0.33 mm.

Relationships.—The two prominent sinuous longitudinal ridges of the median part of the valve serve to distinguish this species. *S. dorsosulcata* Swartz (1932, p. 56) from the Shriver chert of Pennsylvania is a similar species but its surface is more distinctly pitted and lacks the median longitudinal ridges (see also *S. bispinosa*).

Types.—Holotype U.S.N.M. 118056, paratypes U.S.N.M. 118057 a–c.

STREPULITES TYPICUS (Bassler), 1941
Plate 38, figs. 6a–d

Octonariella typica BASSLER, 1941, Jour. Washington Acad. Sci., vol. 31, p. 27, figs. 36, 37.
Strepulites typicus (Bassler) WARTHIN, 1945, Wagner Free Inst. Sci., Type Invert. Fossils of N. A. (Devonian), Thlipsuridae, card 43.

The following description of internal features of the shell is in supplement to Bassler's original description of the external characteristics.

Hinge situated on dorsal slope, mostly in front of position of greatest height. In right valve it consists of an anterior, narrow, elongate, socket-like depression, an interterminal strong bar, formed of the narrowed and extended valve edge and bounded dorsally by a faint groove, and a posterior elongate socket-like depression that is somewhat narrower than the anterior one; both terminal sockets pass into prominent selvage groove that borders free margins of valve; dorsal surface rises markedly above hinge line as valve is viewed laterally. Hinge surface of left valve consists of terminal elongate toothlike elevations; the interterminal area recessed, narrowed above to slightly overlap interterminal portion of right; free margin bears a selvage groove that fits into corresponding furrow in right. Midventral edges of both valves bend inward; and that of right strongly extended as a feature of overlap. Inner lamellae not differentiated. Muscle scar a small rounded node having an irregular surface and situated on a broad low swelling at midlength.

Length of left valve (plate 38, fig. 6a), 1.34 mm.; height, 0.89 mm.; convexity, 0.47 mm.

Types.—Figured specimens U.S.N.M. 118058 a–d.

STREPULITES BISPINOSUS (Bassler)
Plate 38, figs. 8a–f; text fig. 7

Octonariella bispinosa BASSLER, 1941, Jour. Washington Acad. Sci., vol. 31, p. 27, figs. 33–35.
Stibus bispinosus (Bassler) WARTHIN, 1945, Wagner Free Inst. Sci., Type Invert. Fossils of N. A. (Devonian), Thlipsuridae, card 27.

Carapace subovate in side view, highest near middle; dorsal margin moderately arched, with posterior slope slightly the steeper; ventral margin nearly straight, slightly concave medially; terminal margins nearly uniformly rounded with greatest length occurring slightly below midheight. Right valve much larger than left and with a broad, smooth, flattened marginal area that bears a slightly elevated border. Left valve provided with a narrower smooth marginal area. General surface of each valve strongly elevated above margin, posterodorsal surface bears a broad oblique depression or sulcus that contains an oblique narrow low ridge in its trough; anterior surface reticulate or coarsely pitted with the longitudinal elements of the reticulate pattern stronger; a ridge somewhat higher than the others, borders reticulate area behind. Short spines project from crest of marginal rim anterodorsally and anteroventrally in left valve; corresponding spines in right valve are weaker or are lacking.

The hingement and other internal features of this species are like those in *S.*

typicus (Bassler), except that the groove dorsad of the interterminal bar in the right valve is deeper and is more clearly for reception of narrowed hinge edge of left valve.

Length of a figured right valve (plate 38, fig. 8a), 1.06 mm.; height, 0.65 mm.; convexity, 0.40 mm.

Remarks.—This species is very similar to "*Octonaria*" *dorsosulcata* Swartz from the Lower Devonian Shriver chert of Pennsylvania and very probably is descended from it. That species lacks the anterior spines and has a shorter posterior sulcus than *S. bispinosus*. The strong right valve overlap and the broad flattened border prevent assignment to *Stibus* Swartz and Swain as was done by Warthin (1945).

Types.—Figured specimens U.S.N.M. 118061 a–f.

STREPULITES BIFURCATUS (Bassler)
Plate 38, figs. 9a–c; text fig. 10

Octonariella bifurcata BASSLER, 1941, Jour. Washington Acad. Sci., vol. 31, p. 27, fig. 32 [not fig. 33, which is *Strepulites bispinosus* (Bassler)].

Stibus bifurcatus (Bassler) WARTHIN, 1945, Wagner Free Inst. Sci., Type Invert. Fossils of N. A. (Devonian), Thlipsuridae, card 26.

Hingement and other internal features as in *S. bispinosus* (Bassler). Length of figured specimen (pl. 38, fig. 9a), a right valve, 1.01 mm.; height, 0.61 mm.; convexity, 0.30 mm. Despite the elongate, low outline, the presence of a flattened marginal border seems to prevent assignment of the species to *Stibus* as was done by Warthin (1945).

Types.—Figured specimens U.S.N.M. 118062 a–c.

STREPULITES CLAVATULUS (Bassler)
Plate 38, figs. 10a–c; text fig. 5

Octonariella clavatula BASSLER, 1941, Jour. Washington Acad. Sci., vol. 31, p. 27, figs. 30, 31.

Strepulites clavatulus (Bassler) WARTHIN, 1945, Wagner Free Inst. Sci., Type Invert. Fossils of N. A. (Devonian), Thlipsuridae, card 33.

Hingement and other internal structures as in *S. bispinosus* (Bassler) and *S. bifurcatus* (Bassler). Length of figured specimen (plate 38, fig. 10a), 0.77 mm.; height, 0.46 mm.; thickness, 0.40 mm.

Types.—Figured specimens U.S.N.M. 118063 a–c.

Genus STIBUS Swartz and Swain, 1941

Small, subreniform; dorsal margin arched; surface with a group of pits near anterior end and an oblique curving furrow or series of pits parallel to posterior and posterodorsal margin; right valve larger. Hinge surface weakly rabbeted; hinge lies mostly in front of valve middle; muscle scar a median tubercle; inner lamellae apparently present.

Type species.—*Stibus kothornostibus* Swartz and Swain.

Geologic occurrence.—Onesquethaw stage, Devonian.

Remarks.—The orientation of the shell in this genus is uncertain, but the more anterior position of the hinge and more highly ornamented end are used as features comparative to other Thlipsuridae.

STIBUS BINODOSUS Swain, n. sp.
Plate 38, figs. 7a,b

Shell small, elongate, subelliptical in side view; highest medially; dorsal margin moderately convex; ventral margin nearly straight; terminal margins of about equal curvature, the posterior truncated. Right valve larger than left. Convexity of valves moderate; thickest in posterior half.

Anterior end compressed and bears a low, narrow, bordering ridge; an obscure ridge occurs along posterior margin. Middle of each valve bears a deep, large pit, anterad of which a longitudinal furrow extends to anterior compressed portion; on either flank of furrow near its anterior end is a hornlike node that slightly overhangs terminal compressed area. General surface smooth.

Hingement not clearly understood owing to conditions of preservation; hinge surface lies mostly anterad of position of greatest height; hinge of right valve beveled above and weakly rabbeted for reception of overlapping hinge edge of left. Terminal margins of right valve grooved for reception of edge of left. A prominent median tubercle on valve interior represents the external median pit, and probably contains the muscle scar. Inner lamellae apparently are present, but their details were not clearly observed.

Length of holotype, a left valve, 0.52 mm.; height, 0.32 mm.; convexity, 0.13 mm.

Relationships.—The outline and anterior concavity of this species conform to features prescribed for *Stibus* (Swartz and Swain, 1941, p. 436). The prominent anterior nodes serve to separate this species from other described representatives of the genus.

Types.—Holotype U.S.N.M. 118059, paratype U.S.N.M. 118060.

Genus THLIPSURA Jones and Holl, 1869

Medium size, subreniform; dorsal margin strongly convex; highest and thickest in front of middle; anterior end sharply depressed to form a large shelf-like area, open to the front; various modifications of surface ornamentation affect the inner border of this depressed area (after Swartz, 1932).

Type species.—*Thlipsura corpulenta* Jones and Holl.

Geologic range.—Silurian and Devonian.

THLIPSURA FURCOIDES Bassler, 1941
Plate 38, figs. 3a–d; text figs. 11, 12

Thlipsura furcoides BASSLER, 1941, Jour. Washington Acad. Sci., vol. 31, p. 24, figs. 17, 18.
?Thlipsura sp. SWARTZ and SWAIN, 1941, Geol. Soc. America Bull., vol. 52, p. 431, pl. 5, fig. 1.

The characteristics of the interior of the shell in this species are as follows:

Right valve umbonate dorsally; hinge margin beveled on its under side to overlap edge of left; a selvage groove, into which fits a corresponding ridge on left valve, borders free margins. Hinge margin of left valve weakly rabbeted above and bears an apparently unoccupied shallow groove beneath. Muscle scar a slightly anteromedian circular spot consisting of small tubercles radially arranged about a central tubercle. Inner lamellae not differentiated. Midventral margin of each valve curved slightly inward.

Length of right valve (plate 38, fig. 3a), 1.47 mm.; height, 1.00 mm.; convexity of valve, 0.51 mm.; length of left valve (plate 38, fig. 3d), 1.56 mm.; height, 0.97 mm.; convexity, 0.58 mm.

Remarks.—The bulbous median anterior lobe is variable in shape as a result of differing length of the groove that defines it anterodorsally. *Thlipsura* sp. (Swartz and Swain, 1941, p. 431) from the Onondaga formation at Swatara Gap, Pennsylvania, may represent an example of this species.

Types.—Figured specimens U.S.N.M. 118054 a–d.

Genus THLIPSURELLA Swartz, 1932

Like *Thlipsura* but with a distinctly elevated rim bordering anterior margin, and with a median sulcus or dorsoventrally elongated pit.

Type species.—*Thlipsurella ellipsoclefta* Swartz.

Geologic range.—Lower and Middle Devonian.

THLIPSURELLA SECOCLEFTA Swartz, 1932
Plate 38, figs. 4a,b; text fig. 6

Thlipsurella secoclefta SWARTZ, 1932, Jour. Paleontology, vol. 6, p. 46, pl. 10, figs. 8a–e. BASSLER, 1941, Jour. Washington Acad. Sci., vol. 31, p. 26, figs. 21, 22.

The external characteristics of the species were described by Swartz. The interior of the right valve bears the following structures.

Hinge margin a little less than half of shell length, situated on anterodorsal slope in front of position of greatest height; valve surface above hinge slightly umbonate; hinge consists of slightly extended valve edge that evidently overlaps left; bounded below by a narrow rabbet-groove. Free margins bear a selvage groove to receive edge of left. A prominent internal dorsoventrally elongate median swelling represents external median pit. Muscle scar consists of a group of two or three small spots situated on crest of internal swelling. Inner lamellae not differentiated. Midventral margin turned slightly inward.

Left valve not observed.

Length of right valve (plate 38, figs. 4a,b), 0.88 mm.; height, 0.55 mm.; convexity of valve, 0.29 mm.

Occurrence.—The species also occurs in the Shriver chert, Deerpark stage, of Pennsylvania.

Type.—Figured specimen U.S.N.M. 118055.

Family KLOEDENELLIDAE Ulrich and Bassler, 1923

"Straight-hinged, more or less inequivalved small Ostracoda, usually the right valve overlapping the left around the free edges and provided with a small process in the postdorsal angle that fits into a corresponding depression in the opposite valve. Valves shallowly unisulcate to deeply quadrilobate with practically complete transition from one extreme to the other." (Ulrich and Bassler, 1923, p. 312.) The authors considered the cardine hinge process to be posterior, thus placing the more prominent sulci posterior and the dimorphic swellings found in certain kloedenellids, anterior.

Swartz (1933, p. 238) reversed this orientation and stated that the Kloedenellidae

are characterized by "(1) the rhomboidal outline, with a prominent posterior cardinal angle, no distinct anterior angle, comparatively full antero-ventral region, and the straight or even sinuate ventral margin, and, (2) the post-dorsal position of the broad inflation." Swartz also stated that in his opinion the Kloedenellidae along with the Glyptopleuridae differed sufficiently from the Beyrichiidae to require their removal from the Beyrichiacea. According to him (Swartz, 1933, p. 239), "The oblong rhomboidal outline, and the post-dorsal position of the female inflations or thickenings, are suggestive of certain members of the Cytheracea."

Genus THLIPSURINA Bassler, 1941

"Similar to *Thlipsura* in general shell characters but differing in the absence of a posterior sulcus and in the presence of a broad, shallow, transverse, median depression and of a flattened anterior end bounded by a sharp ridge which in turn is followed typically by a broad, deep, curved sulcus expanding in width from the hinge line to the ventral margin. Surface marking alike on both valves." (Bassler, 1941, p. 26.)

The present writer believes that the relatively straight hinge margin, apparent dimorphism (see discussion of *T. elongata* below), and prominent sulcation in the anterior half provide a closer relationship of this genus to the Kloedenellidae than to the Thlipsuridae. The lack of cardine anterior hinge process and poorly defined postcardinal angle, however, are not typical of the kloedenellids and suggest that the genus represents a transition to the Thlipsuridae. *Poloniella* Gurich may represent a similar transitional genus as suggested by Swartz (1933, pp. 240–241).

The internal characteristics of the Kloedenellidae are not well known. These features in *Thlipsurina* are described below. This genus as well as the other more characteristic kloedenellids apparently represent the most primitive group of ostracodes with midventral incurvature of the valve margins, a feature characteristic of both the Cypridae and the Cytheridae.

THLIPSURINA ELONGATA Bassler, 1941
Plate 37, fig. 10; plate 38, figs. 2a–d; text figs. 8,9

Thlipsurina elongata BASSLER, 1941, Jour. Washington Acad. Sci., vol. 31, p. 26, figs. 23, 24.

Thlipsurina similis BASSLER, 1941, ibid., fig. 26.

The following description of internal features of the shell will supplement Bassler's description of the exterior.

Hinge line nearly straight, about two-thirds of shell length, with broadly obtuse postcardinal angle, and much less obtuse anterocardinal angle. Hinge margin of left valve consists of terminal elongate eleva-

EXPLANATION OF PLATE 37

FIGS. *1a–d—Primitiella* cf. *P. inornata* (Ulrich). *1a*, right valve exterior; *1b*, right valve interior; *1c*, left valve exterior; *1d*, left valve interior; ×20. USNM 118042 a–d. (p. 262)

2a, b—Primitiella? nuculiforma Swain, n. sp. *2a*, exterior of holotype left valve; *2b*, exterior paratype right valve; ×22. USNM 118043, 118044. (p. 264)

3a–g—Bollia planojugosa Swartz and Swain. *3a–d*, exterior and interior views and a dorsal view of four left valves; *3e*, exterior of immature right valve; *3f, g*, exteriors of two immature left valves; ×20. USNM 118045 a–e. (p. 265)

4a–g, 5a, b—Bollia ungulata Bassler. *4a*, right valve exterior; *4b*, immature left valve interior; *4c*, immature left valve exterior; *4d*, immature left valve exterior; *4e*, right valve interior; *4f*, immature right valve exterior; *4g*, dorsal view of immature left valve; *5a, b*, exterior views of two early molts of left valves; ×22. USNM 118046 a–g. (p. 266)

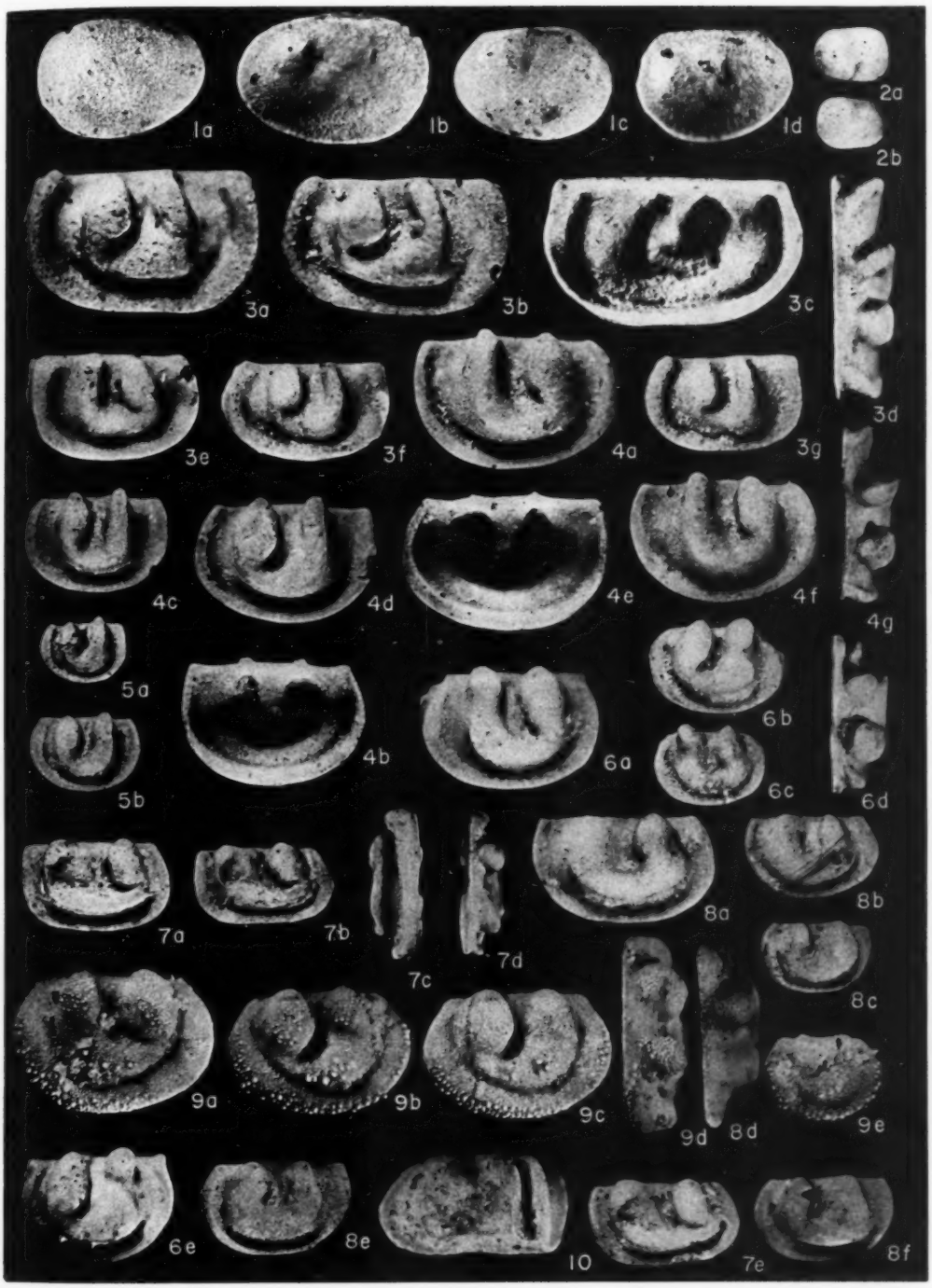
6a–e—Bollia ungulata var. *bassleri* Swain, n. var. *6a*, exterior of holotype, a right valve; *6b*, exterior of immature paratype left valve; *6c*, exterior of an early molt right valve paratype; *6d, e*, dorsal and side views of a left valve paratype; ×20. USNM 118047 a–d. (p. 268)

7a–e—Bollia tribolbina Bassler. *7a, c*, side and ventral views of a right valve; *7b*, side view of right valve; *7d, e*, ventral and side views of a right valve; ×22. USNM 118048 a–c. (p. 268)

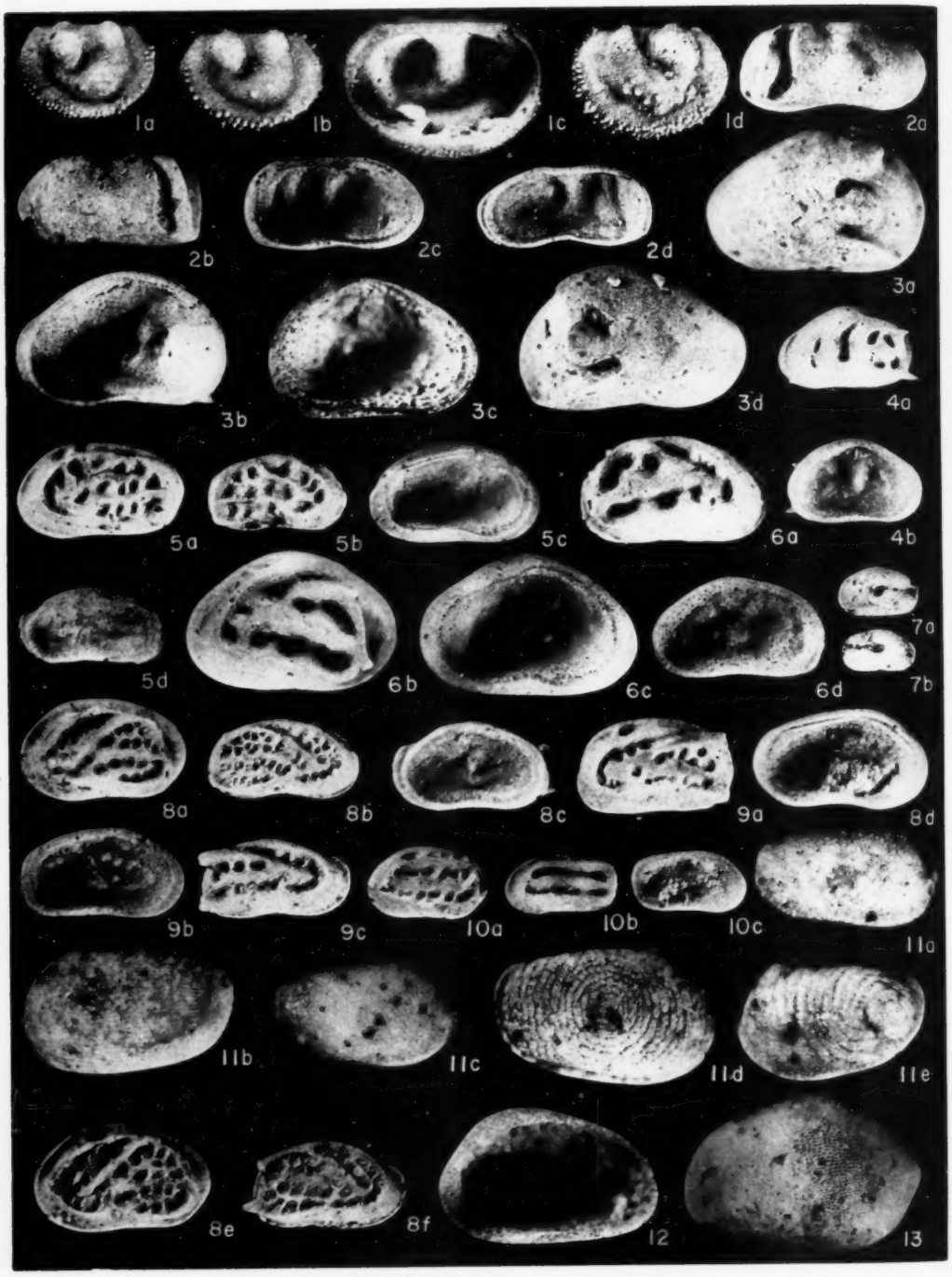
8a–f—Bollia ungulata var. *depressa* Swain, n. var. *8a, d*, exterior and dorsal views of holotype right valve; *8b, c*, exterior views of two paratype right valves; *8e, f*, exterior views of two paratype left valves; ×20. USNM 118049 a–e. (p. 268)

9a–e—Bollia obesoides Bassler. *9a*, right valve exterior; *9b, c*, immature left valve exteriors; *9d*, dorsal view of a left valve; *9e*, exterior of an early molt left valve; ×20. USNM 118050 a–e. (p. 268)

10—Thlipsurina elongata Bassler. Exterior of a right? valve, possibly a female dimorph; ×22. USNM 118051. (p. 276)



Swain, Devonian Ostracoda from Tennessee



Swain, Devonian Ostracoda from Tennessee

tions that are the dorsal ends of a prominent selvage ridge paralleling free margins; intervening hinge edge slightly recessed. Hinge of right valve correspondingly consists of terminal elongate depressions that pass around free margins into a selvage groove; intervening hinge edge slightly extended and beveled below to overlap edge of left. Terminally in left valve, selvage ridge lies well within valve margin so that ends of this valve extend slightly beyond the right. Along ventrum, edge of right valve extends beyond left. Midventral margin of each valve curved inward. External ridges and sulci represented by converse features on interior surface; muscle scar an obscure dorsoventrally elongated spot lying on the transverse ridge that represents external median sulcus. Inner lamellae narrow and fused to interior surface posteriorly; not clearly differentiated elsewhere.

Length of left valve (plate 38, fig. 2a), 1.20 mm.; height, 0.51 mm.; convexity, 0.34 mm.; length of right valve (plate 38, fig. 2b), 1.18 mm.; height, 0.62 mm.; convexity, 0.40 mm.

Remarks.—*Thlipsurina similis* Bassler is believed to represent the female dimorph of *T. elongata*, as the deepening of the median sulcus in *T. similis* apparently is a function of the increase in posterior convexity. The relatively straight hinge margin, apparent dimorphism, and prominent sulcation in the anterior half provide a relationship of this species to the Kloedenellidae, particularly to *Dizygopleura* Ulrich and Bassler, rather than to the Thlipsuridae.

Types.—Figured specimens U.S.N.M. 118051, 118053 a–d.

Family Healdiidae Harlton, 1933

"Small, mostly subovate, subtriangular or elongate, corneocalcareous shells with thin, unequal valves, the margin of one valve overlapping the other completely; surface with one or two ridges, or posteriorly with spines or both." (Harlton, 1933, p. 26).

Explanation of Plate 38

Figs. *1a–d—Bollia obesoides* Bassler. *1a, b*, exterior views of two immature left valves; *1c* interior of a right valve (see plate 37, fig. *9a*); *1d*, exterior of immature right valve; ×20. USNM 118052 a–c (p. 268)

2a–d—Thlipsurina elongata Bassler. *2a*, exterior of a possible male left valve; *2b*, exterior of a possible male right valve; *2c*, interior of a possible male right valve; *2d*, interior of a possible male left valve; ×22. USNM 118053 a–d. (p. 276)

3a–d—Thlipsura furcoides Bassler. *3a*, right valve exterior; *3b*, left valve interior; *3c*, right valve interior; *3d*, left valve exterior; ×23. USNM 118054 a–d. (p. 275)

4a, b—Thlipsurella secoclefta Swartz. Exterior and interior views of a right valve; ×22. USNM 118055. (p. 275)

5a–d—Strepulites swartzi Swain, n. sp. *5a*, exterior of holotype, a right valve; *5b*, exterior of paratype left valve; *5c*, interior of paratype right valve; *5d*, exterior of paratype left valve; ×20. USNM 118056, 118057 a–c. (p. 272)

6a–d—Strepulites typicus (Bassler). *6a*, exterior of a left valve; *6b*, exterior of a right valve; *6c*, interior of a right valve; *6d*, interior of a left valve; ×20. USNM 118058 a–d. (p. 273)

7a, b—Stibus binodosus Swain, n. sp. *7a*, exterior of holotype, a right valve; *7b*, exterior of paratype left valve; ×20. USNM 118059, 118060. (p. 274)

8a–f—Strepulites bispinosus (Bassler). *8a*, exterior of a right valve; *8b*, exterior of a left valve; *8c*, interior of a left valve showing muscle tubercle; *8d*, interior of a right valve; *8e*, exterior of a right valve; *8f*, exterior of a left valve showing the spines; ×20. USNM 118061 a–f. (p. 273)

9a–c—Strepulites bifurcatus (Bassler). *9a*, exterior of a right valve; *9b*, interior of a right valve; *9c*, exterior of a left valve; ×20. USNM 118062 a–c. (p. 274)

10a–c—Strepulites clavatulus (Bassler). *10a*, right side of a complete carapace; *10b*, exterior of an immature right valve; *10c*, interior of an immature right valve; ×20. USNM 118063 a–c. (p. 274)

11a–e—Graphiodactylus sp. aff. *G. lineatus* (Ulrich and Bassler). *11a, c*, exterior views of two right valves; *11b*, exterior of a left valve; *11d*, right side of a carapace in which silicification has produced Beekite rings; *11e*, exterior of an immature left valve showing anterior spine that is apparently lacking on mature left valves; surface with Beekite rings; ×22. USNM 118064 a–e. (p. 270)

12—Pachydomella multitubulis (Swartz and Swain). Interior of a left valve; ×22. USNM 118065. (p. 282)

13—Pachydomella thlipsuroidea Swain, n. sp. Exterior of a paratype left valve; ×22. USNM 118066. (p. 280)

Three genera, i.e., *Healdia* Roundy, *Seminolites* Coryell, and *Cavellina* Coryell, were included in this family by Harlton under the original description. If this association is valid these genera would probably be placed in the family Cytherellidae, because *Cavellina* is almost certainly a member of that family (Kellett, 1935, p. 144). *Cavellina* and other typical cytherellids are characterized by right valve overlap whereas *Healdia* and *Seminolites* have left valve overlap, a difference, that considering other groups of ostracodes, does not necessarily hold true, but nevertheless suggests a fundamental, possibly phylogenetic disassociation.

One of Harlton's species, *Seminolites perforatus* Harlton, from the Johns Valley (Pennsylvanian) shale is much like *Stibus* Swartz and Swain of the Thlipsuridae, in general shape, weak curved anterior (?) groove, and large surface pits in median and posterior (?) region. The posterior transverse ridges of *S. perforatus* that provide a relationship to the Healdiidae are lacking in *Stibus*. The Thlipsuridae, and in particular the thlipsurellid ostracodes, may have been ancestral to the Healdiidae. The possible relationship between the latter family and the Cytherellidae is not clear.

Genus HEALDIA Roundy, 1926

Ovate, left valve larger and grooved to receive edge of right, overlapping strongly except along posterodorsal slope; surface smooth or pitted; posterior portion with two backward-pointing spines, or with a curved ridge or shallow groove parallel to margin (Bassler and Kellett, 1934).

Type species.—*Healdia simplex* Roundy.

Geologic range.—Devonian to Permian.

HEALDIA CAMDENENSIS (Bassler) Swain, new name

Plate 39, figs. 6a-e; text figs. 13,14

Thlipsurina simplex BASSLER, 1941, Jour. Washington Acad. Sci., vol. 31, p. 26, fig 25.

(not) *Healdia simplex* ROUNDY, 1926, U. S. Geol. Survey Prof. Paper 146, p. 8, pl. 1, figs. 11a–c.

Shell subovate in side view; highest medially; dorsal margin of left valve moderately convex, right weakly convex; ventral margin nearly straight in left valve, slightly concave medially in right; anterior margin a little more narrowly rounded than posterior, the latter slightly extended medially in left valve, truncate above and below. Left valve larger than right. Valves moderately convex, greatest thickness postmedian.

A prominent transverse ridge occurs near posterior end; it merges more or less gradually with surface on its anterior flank but strongly overhangs the compressed posterior end. General surface anterad of ridge, finely pitted in well-preserved specimens; pits best developed and deepest post-medially.

Hinge line of left valve grooved for reception of weakly rabbeted edge of right; along dorsal slopes, groove in left valve is slightly broader and deeper and there are corresponding slight terminal elevations in right; free margin of left valve bears a prominent selvage groove to receive right valve. Muscle scar an obscure, slightly anteromedian, rounded spot, Inner lamellae very narrow and with a slight vestibule anteriorly in left valve, not clearly differentiated elsewhere.

Length of left valve (plate 39, fig. 6d), 1.03 mm.; height, 0.58 mm.; convexity, 0.31 mm.

Remarks.—The outline, hingement and posterior transverse ridge of this species provide a relationship with *Healdia* Roundy rather than with *Thlipsurina* Bassler which bears a prominent median sulcus. A closely related form is *Thlipsurella* (?) *curvi-cristata* Swartz and Swain (1941, p. 434) from the Onondaga formation of Pennsylvania, but in that species there is a distinct depression anterad of the terminal ridge.

Types.—Figured specimens U.S.N.M. 118073 a–e.

Family Uncertain

Genus RANAPELTIS Bassler, 1941

The external characteristics of the genus were described by Bassler (1941, p. 26) and by Swartz and Swain (1941, p. 441). The Camden chert specimens provide additional information about the internal structures as described below under *R. typicalis* Bassler.

Type species.—*Ranapeltis typicalis* Bassler.

Geologic range.—Onesquethaw stage.

Remarks.—The genus has been previously referred to the family Thlipsuridae (Bassler, 1941; Warthin, 1945) but Swartz and Swain recognized the uncertainty of this assignment owing to the pointed posterior end and

the nature of the ornamentation. They (Swartz and Swain, 1941, p. 441) suggested a relationship of *Ranapeltis* to the Beecherellidae, particularly to *Acanthoscapha pentagonalis* Swartz of the Lower Devonian.

The present writer feels that the outline, hingement, inner lamellae, musculature, and ventral ridges, suggest a relationship to *Pseudocypris* Daday and *Tuberocyproides* Swain of the family Cypridae.

RANAPELTIS TYPICALIS Bassler, 1941
Plate 39, figs. 8a–c; text figs. 19,20

The internal structures of the species are as follows:

Hinge margin nearly straight and about half of shell length; hinge margin grooved for reception of slightly rabbeted edge of right. Bordering free margins in left valve is a prominent selvage groove into which fits margin of right. Anterior end bears a row of small spines bordering outer margin; pointed posterior end bears a single bluntly spinose projection. Inner lamellae narrow with a slight vestibule in well-preserved examples. Midventral margin of each valve curved strongly inward. Muscle scar consists of a large median circular spot composed at least partly of radiating spots around a central spot.

Length of left valve (plate 39, fig. 8b), 1.56 mm.; height, 0.91 mm.; convexity, 0.55 mm.

Types.—Figured specimens U.S.N.M. 118075 a–c.

RANAPELTIS UNICARINATA Bassler, 1941
Plate 39, figs. 7a–c.

Ranapeltis unicarinata BASSLER, 1941, Jour. Washington Acad. Sci., vol. 31, p. 27, fig. 29.
Ranapeltis dicarinata SWARTZ and SWAIN, 1941, Geol. Soc. America Bull., vol. 52, p. 402, pl. 6, figs. 1 a–f.

The internal features of this species are the same as in *R. typicalis* Bassler. *R. dicarinata* Swartz and Swain from 25 feet above base of Onondaga formation at New Bloomfield, Pennsylvania, is a synonymous species. This horizon represents the *Bollia ungula* zone.

Length of right valve (plate 39, fig. 7a), 1.55 mm.; height, 0.79 mm.; convexity, 0.50 mm.

Types.—Figured specimens U.S.N.M. 118074 a–c.

Family CYPRIDAE Baird, 1846, or BAIRDIIDAE Sars, 1887
Genus CAMDENIDEA Swain, n. gen.

Shell subtriangular to subquadrate in side view; hinge margin convex; ventral margin nearly straight, slightly concave anteromedially; terminal margins narrowly rounded, extended below, the posterior more acuminate than the anterior. Terminoventral regions of shell slightly compressed. Left valve larger than right. Valves moderately convex, thickest midventrally. Surface smooth.

Hinge about half of shell length, nearly straight; consisting of a weak groove in hinge face of left valve and in right valve of a corresponding weak ridge bounded dorsally by a slight incisure. Free margins of left valve grooved for reception of edges of right. Midventrally edges of valves sharply incurved. Inner lamellae of moderate width ventrally and terminoventrally, narrow elsewhere; line of concrescence and inner margin slightly separated terminally. Muscle scar a large medially placed spot, bordered by a shallow groove and consisting of numerous smaller slightly elevated spots; accessory spots occur anteroventral of the main spot.

Type species.—*Camdenidea camdenensis* Swain, n. sp.

Geologic range.—Ulsterian series.

Relationships.—This genus exhibits features of the shell that relate it both to the Cypridae and to the Bairdiidae. The ventral position of the greatest length and the accessory spots anteroventral to the main muscle scar, as well as the general outline and the nature of the inner lamellae provide a close relationship to *Cypris* O. F. Müller. The short, rather broad hinge and the circular main muscle scar are features more characteristic of the Bairdiidae. For the present the new genus will be placed with the Cypridae, and probably represents a member of the ancestral stock of that family.

Some species of the living cyprid ostracode *Chlamydotheca* Saussure are very close to *Camdenidea* in shape, terminal compression of the valves and in musculature, but in *Chlamydotheca* the ends, particularly the anterior, are extended as flanges beyond the line of commissure.

Beecherella bloomfieldensis Swartz and Swain (1941, p. 444) from the Onondaga of

Pennsylvania should be referred to *Camdenidea*. A species tentatively identified as belonging in *Condracypris* Roth from the Haragan marl of Oklahoma was kindly shown to the writer by I. G. Sohn of the U. S. Geological Survey; this species closely resembles *Camdenidea camdenensis*. It is of interest to note that a questionable species of *Condracypris*, *C.* (*?*) *kirkbyi* (Jones) has been described from the Onondaga limestone of New York.

CAMDENIDEA CAMDENENSIS Swain, n. sp.
Plate 39, figs. 10a–g

Shell elongate-subtriangular in side view; dorsal margin strongly convex; ventral margin slightly concave; anterior margin narrowly rounded, strongly extended below; posterior margin sharply pointed, strongly extended below. Left valve only slightly larger than right but overlapping the other along free margins. Valves moderately convex; greatest thickness median and in ventral half.

Ventral surface rises abruptly from margin; a weak ridge forms crests of this rise in postventral region; dorsad of ridge posterior surface of shell somewhat flattened. Posterior, pointed end of shell compressed near margin; a similarly narrow compressed zone occurs along anterior margin. General surface of valves smooth.

Hinge surface nearly straight, and about two-fifths of shell length; its characteristics are as described for this genus. Free margin of left valve bears a well-defined groove for reception of edge of right. Features of the inner lamellae are as described for the genus. Muscle scar consists of a large medially placed circular spot, bordered by a shallow groove and consisting of several slightly elevated spots, together with two additional spots lying anteroventral of the main group.

Length of holotype, a left valve, 1.76 mm.; height, 1.00 mm.; convexity, 0.58 mm. Length of a bivalved paratype (plate 39, fig. 10d) that is incomplete dorsally, 1.5 mm.; thickness, 0.88 mm.

Relationships.—Camdenidea bloomfieldensis (Swartz and Swain) (1941, p. 444) is similar to the present species in general shape, but bears ventroterminal ridgelike extensions of the valve surface along the crest of the abrupt rise from the valve margin.

Specimens in the collections of the U. S. Geological Survey from the Haragan marl at White Mound, Oklahoma, are much like the present species. The Haragan marl is considered to be Helderbergian in age.

Types.—Holotype U.S.N.M. 118077, paratypes U.S.N.M. 118078 a–f.

Family Uncertain
Genus PACHYDOMELLA Ulrich, 1891

Tubulibairdia SWARTZ, 1936, Jour. Paleontology, vol. 10, p. 581.

"Carapace exceedingly ventricose; valves thick and strong, the left much the larger, its thick edges overlapping the right valve at all sides. Dorsal side strongly arched, ventral edge more nearly straight, ends subequal. A faintly impressed, sub-central umbilical pit" [muscle scar impression]. (Ulrich, 1890, p. 198.)

Type species.—Pachydomella tumida Ulrich.

Geologic range and occurrence.—Ordovician—Devonian. North America, Europe, Australia.

Remarks.—The holotype of *Pachydomella tumida* Ulrich was kindly examined by I. G. Sohn of the U. S. Geological Survey, and found to contain normal canals. *Tubulibairdia* Swartz is a synonym as it is similar in shape and overlap and likewise possesses deep normal canals. *Phanassymetria quadrupla* Roth (type species) was also examined and found to be very closely related to, if not the same as, *Pachydomella*.

The family relationships of *Pachydomella* are obscure but because of its thick-walled inequivalved shell and general outline it may belong in the Barychilinidae Ulrich.

PACHYDOMELLA THLIPSUROIDEA
Swain, n. sp.
Plate 38, fig. 13; plate 39, figs. 3a–c

Shell subovate in side view; highest about one-third from posterior end. Hinge margin moderately convex in left valve, gently convex in right; ventral margin nearly straight in left valve, slightly concave medially in right; anterior margin broadly rounded, slightly extended below, subtruncate above; posterior margin extended as a blunt point one-third to one-half distance from ventrum, subtruncate above and below this position in left valve, subtruncate to slightly concave above in right. Left valve larger than right, overlapping and extending strongly beyond the other terminally and ventrally, less strongly dor-

sally. Valves strongly convex, greatest thickness posterad of midlength.

Posterodorsal third to half of each valve surface delicately and finely reticulate; in right valve a prominent longitudinal curved furrow extends from posterior margin to midlength; venterad of furrow near posterior end valve surface somewhat elevated to form a broad ridge. Corresponding furrow and ridge absent in left valve. Remainder of valve surfaces smooth; in right valve a lobe of the smooth surface extends into reticulated surface about at midheight. In some specimens ends of normal canals, not reaching exterior, can be seen through shell.

Hinge nearly straight and slightly less than half of shell length; in right valve hinge face bears a narrow groove for reception of simple edge of left; obscure elongate elevations occur at ends of hinge in right valve, with corresponding depressions in left. Midventral portion of outer margin in right valve strongly extended and slightly curved toward interior. Inner lamellae broad midventrally, narrow elsewhere; line of concrescence and inner margin slightly separated. Normal canals large, widely and irregularly spaced, not opening to exterior; radial canals numerous, large, closely spaced, and occurring around entire free margin. Muscle scar consists of a large, circular, slightly depressed spot lying anterad of midlength; a tiny accessory spot occurs anteroventral to the main spot.

Length of holotype, a right valve, 1.47 mm.; height, 0.89 mm.; convexity, 0.66 mm.; length of paratype, a left valve, 1.52 mm.; height, 1.19 mm.; convexity, 0.75 mm.

Relationships.—The general shape and features of the posterior end of the shell of this species are like the Thlipsuridae Ulrich, but the well-developed normal canals and calcified inner lamellae are bases for separation from that family. A closer relationship to the Barychilinidae Ulrich is indicated by the thick, strongly convex, inequivalved subovate shell, although the prominent anteromedian ? pit of *Barychilina* is lacking in *Pachydomella*.

Types.—Holotype U.S.N.M. 118069, paratypes U.S.N.M. 118066, 118070 a,b.

PACHYDOMELLA DORSOCLEFTA Swain, n. sp.
Plate 39, figs. 4a–c; text figs. 17,18

Shell subovate in side view; highest medially in left valve, postmedially in right valve; dorsal margin moderately convex; ventral margin nearly straight in left valve, slightly concave medially in right; anterior margin broadly rounded, slightly extended below, posterior margin narrowly rounded, extended and subacuminate below. Left valve much larger than right and strongly overlapping it. Valves strongly convex, greatest thickness about one-third from posterior end.

Left valve bears a deep longitudinal groove near and parallel to dorsal margin; dorsad of groove, surface of valve raised to form a ridge-like swelling that in side view extends beyond hinge margin; posterior fifth of left valve somewhat compressed; general surface smooth. In right valve, posterior portion somewhat compressed, and posterodorsal surface swollen to extend beyond hinge margin, but dorsal longitudinal groove is lacking, general surface of valve smooth but terminations of normal canals beneath surface appear as small opaque spots.

Hinge of right valve obscurely rabbeted for reception of overlapping hinge margin of left; terminal portions of hinge in right valve slightly elevated as elongated ridges; corresponding elongate shallow depressions occur in left valve. Midventral margin of each valve extended and curved slightly inward. Free margins of overlapping left valve weakly grooved, and free margins of right correspondingly flanged. Inner lamellae moderately broad midventrally, narrow terminally; line of concrescence and inner margin slightly separated terminally. Normal canals large, widely and irregularly spaced, not reaching exterior surface; radial canals as seen in a few specimens, broken along margin, are large, numerous and closely spaced. Muscle scar not as well differentiated as in the preceding species; it is a roughly circular spot that contains a few obscure markings.

Length of holotype, a left valve, 1.29 mm.; height, 0.79 mm.; convexity, 0.42 mm.

Relationships.—The longitudinal dorsal groove seems to distinguish this species. It is a fundamentally different shell form from that in *P. thlipsuroidea*, n. sp., in that the left valve rather than the right is the more strongly ornamented. *P. tubulifera* (Swartz) (1936, p. 581) from the Shriver chert of Pennsylvania has a flattened area bordering the hinge in the left valve and a slight suggestion of a groove venterad of this flattened

area (Swartz, 1936, pl. 89, fig. 20). The Shriver species appears to be directly ancestral to *P. dorsoclefta*, n. sp.

Types.—Holotype U.S.N.M. 118071, paratypes U.S.N.M. 118072 a,b.

PACHYDOMELLA MULTITUBULIS
(Swartz and Swain), 1941
Plate 38, fig. 12; plate 39, figs. 5a–c

Tubulibairdia multitubulis SWARTZ and SWAIN, 1941, Geol. Soc. America Bull., vol. 52, p. 445, pl. 5, fig. 9.
Tubulibairdia paucitubulis SWARTZ and SWAIN, ibid., figs. 8a–c.

Shell elongate-ovate in lateral view; highest about one-third from posterior end. Dorsal margin of left valve moderately convex, sloping much more steeply behind than in front of position of greatest height; dorsal margin of right valve slightly convex. Ventral margin nearly straight in left valve, slightly concave medially in right. Anterior margin rounded, slightly extended below, subtruncate above; posterior margin extended medially to ventromedially, truncate above and below. Left valve much larger than right, overlapping and extending strongly beyond the other, except anteriorly. Valves strongly convex, greatest thickness postmedian; surface posterad of position of greatest thickness slopes steeply to posterior margin. Surface smooth; ends of normal canals, not reaching surface, visible through shell in well-preserved specimens.

Hinge line recessed, with dorsal surface in left valve strongly swollen above hinge, less strongly in right valve. Hingement simple; hinge edge of right valve beveled above and overlapped by edge of left. Strong flanges on dorsal slopes of left valve project into right. Midventral portion of each valve strongly extended as a feature of overlap. Inner lamellae of moderate width midventrally, narrow terminally in left valve, absent in right valve; line of concrescence and inner margin separated terminally in left valve. Normal canals in adult shells large, widely and irregularly spaced; in smaller immature molts normal canals are present only in posterior portion of valve. Muscle scar not clearly observed. Interior of each valve bears a low transverse ridge about one-third from anterior end, a feature reminiscent of *Cavellina* Coryell.

Length of complete shell (plate 39, fig. 5a), 1.34 mm.; height, 0.82 mm.; thickness, 0.84 mm.

Remarks.—The shape and distribution of normal canals and anteromedian internal transverse ridge of the present specimens provide a comparison with *P. multitubulis* (Swartz and Swain) from the Onondaga formation of Pennsylvania. *P. paucitubulis* (Swartz and Swain) from the same locality is now thought to represent an immature molt of the species. *P. windomensis* (Swartz and Oriel) (1948, p. 563) from the Windom beds, Middle Devonian, of New York has the anterior end more broadly rounded than in the present species and has a pitted surface.

Types.—Figured specimens U.S.N.M. 118065, 118081 a,b,c.

PACHYDOMELLA ? sp.
Plate 39, fig. 9

A single left valve, probably an immature molt of *Pachydomella* is illustrated because of the striking difference from the mature shell in shape and other features. The suggested relationship to this genus is based upon the presence of obscure, but coarse pores in the shell wall, together with the nature of the marginal zone at the narrowly rounded posterior (?) end. An obscure rounded median swelling occurs about two-fifths from anterior end. A suggestion of weak pitting occurs in posterior portion, but this may be due to silicification. A strong internal elevation lying on a broad transverse swelling occurs slightly anterad of mid-length; this swelling evidently represents the muscle scar.

Length, 0.69 mm.; height, 0.50 mm.; convexity, 0.24 mm.

Remarks.—The steep posterior slope, obscure submedian swelling and general shape of this form caused the writer to first refer it to *Condracypris* Roth but that genus bears better developed transverse ridges. The shape is similar to some members of the family Cypridae but the characteristic inward deflection of the ventral margin of that family (together with the Cytheridae) is lacking. The transverse inner ridge is suggestive of the Primitiidae, but the straight hinge of that family is lacking. If the specimen is a young *Pachydomella*, the ontogenetic development of that genus apparently involves: (1) change from subtriangular-compressed to oblong-inflated form, (2) development of midventral incurvature of valve margins, (3) loss of the primitiid-like

inner transverse ridge containing the muscle scar, and (4) growth of narrow inner lamellae.

There is, therefore, a possible ancestral relationship between the Primitiinae and *Pachydomella* although it is not now clear to what other larger group of ostracodes this genus is allied.

Type.— Figured specimen U.S.N.M. 118076.

Family uncertain

Genus MONOCERATINA Roth, 1928

Elongate, subquadrate; dorsal margin long and straight, anterior end rounded; posterior end caudate, extended above; posteroventral surface with laterally or posteriorly projecting spines or alae. Hinge consists of simple groove-and-ridge arrangement at least in Mesozoic representatives. Muscle scar a median vertical row of three or four spots in Jurassic species (after Swartz, 1936; Triebel and Bartenstein, 1938; Swain and Peterson, 1951).

Type species.—*Monoceratina ventrale* Roth.

Geologic range.—Devonian to middle Tertiary.

MONOCERATINA COOPERI Swain, n. sp.
Plate 39, figs. 11a,b

Shell subelliptical in lateral view; dorsal margin slightly convex; ventral margin gently convex; anterior margin broadly rounded, extended below; posterior margin more narrowly rounded, strongly extended above and bluntly caudate in right valve. Left valve larger than right. Ventral surface of each valve expanded to form an ala that is sharp-crested, overhangs ventral surface, and terminates posteriorly in a short spine. General surface smooth, although appearing slightly granular in present specimens, perhaps due to silicification.

Hingement consists of a groove in the rather broad hinge face of left valve for reception of edge of right. Muscle scar consists of a circular spot located anterad of midlength and well below midheight. Inner lamellae not clearly differentiated.

Length of holotype, a left valve, 0.68 mm.; height, 0.40 mm.; convexity, 0.22 mm.

Relationships.—This species has shorter ventral alae and spines than most other Paleozoic representatives of *Monoceratina*. It is closely related in form to some species of *Cytheropteron* and *Cytherura* but differs from those genera in hingement and musculature. Species of Mesozoic and Cenozoic ostracodes assigned to *Monoceratina* differ from the present species in having a vertical row of about four muscle spots.

The family relationships of *Monoceratina* are uncertain. The Mesozoic and Cenozoic representatives have been placed in the family Cytheridae but the simple hinge, lack of accessory muscle scars anterior to the main group, and lack of incurvature of the midportion of the ventral margin suggest that it is not a cytherid.

Types.—Figured specimens U.S.N.M. 118079 (holotype), 118080 (paratype).

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EXPLANATION OF PLATE 39

FIGS, *1a, b—Graphiodactylus?* sp. *1a*, exterior of a right valve having Beekite rings on surface; *1b*, interior of a right valve; ×24. USNM 118067 a, b. (p. 271)

2a–c—Amphissites lunatus Bassler. *2a, c*, exterior and interior views of a left valve; *2b*, exterior of a right valve; ×22. USNM 118068, a, b. (p. 271)

3a–c—Pachydomella thlipsuroidea Swain, n. sp. *3a*, exterior of holotype, a right valve; *3b*, exterior of paratype left valve; *3c*, interior of paratype right valve; ×20. USNM 118069, 118070 a, b. (p. 280)

4a–c—Pachydomella dorsoclefta Swain, n. sp. *4a*, exterior of holotype, a left valve; *4b*, interior of a large paratype left valve; *4c*, interior of a small paratype right valve; ×23. USNM 118071, 118072 a, b. (p. 281)

5a–c—Pachydomella multitubulis (Swartz and Swain). *5a*, right side of a complete carapace; *5b*, interior of a small left valve; *5c*, ventral view of a complete carapace; ×22. USNM 118081 a–c. (p. 282)

6a–e—Healdia camdenensis (Bassler) Swain, new name. *6a*, exterior of a small left valve; *6b*, interior of an early molt left valve; *6c*, exterior of an early molt left valve; *6d*, interior of a large left valve; *6e*, interior of a right valve; ×22. USNM 118073 a–e. (p. 278)

7a–c—Ranapeltis unicarinata Bassler. *7a*, exterior of a right valve; *7b*, interior of a right valve; *7c*, interior of a small left valve; ×23. USNM 118074 a–c. (p. 279)

8a–c—Ranapeltis typicalis Bassler. *8a*, interior of a small right valve; *8b*, exterior of a left valve; *8c*, interior of a left valve; ×22. USNM 118075 a–c. (p. 279)

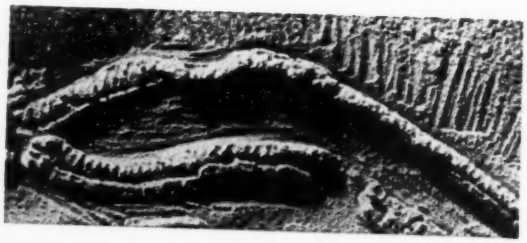
9—Pachydomella? sp. Immature molt of a left? valve; ×22. USNM 118076. (p. 282)

10a–g—Camdenidea camdenensis Swain, n. gen., n. sp. *10a*, exterior of a paratype right valve; *10b*, interior of holotype, a left valve; *10c*, exterior of a paratype left valve; *10d*, ventral view of a paratype; *10e*, interior of right valve, filled with matrix; *10f*, immature right valve; *10g*, right valve exterior; ×21. USNM 118077, 118078 a–f. (p. 280)

11a, b—Monoceratina cooperi Swain, n. sp. *11a*, exterior of holotype, a left valve; *11b*, exterior of paratype left valve; ×22. USNM 118079, 118080. (p. 283)

Swain, Devonian Ostracoda from Tennessee

1



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Harker and Hutchinson, *Gogia prolifica* Walcott

JOURNAL OF PALEONTOLOGY, VOL. 27, NO. 2, PP. 285–287, PL. 40, MARCH 1953

A NEW OCCURRENCE AND REDESCRIPTION OF *GOGIA PROLIFICA* WALCOTT[1]

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ABSTRACT—A new occurrence of the primitive pelmatozoan, *Gogia prolifica* Walcott is located on Mount Kitchener, Alberta, Canada. It is associated with a Middle Cambrian trilobite fauna. The specimens on which the redescription is based show well-preserved cover-plates. The systematic position of the genus is discussed and it is referred to the Eocrinoidea of Jaekel.

INTRODUCTION

DURING field work in the Rocky Mountains of Alberta, Canada, in 1951, a well-preserved Cambrian fauna was discovered by one of the authors (P. Harker) on Mount Kitchener, which lies just west of the Banff-Jasper Highway near the Columbia Icefields. The fauna includes abundant remains of a primitive pelmatozoan, identified as *Gogia prolifica* Walcott. The specimens show structures which were not described by Walcott and which have some bearing on the systematic position of this and other similar early pelmatozoans.

STRATIGRAPHY

Walcott's original specimens of *Gogia prolifica* were collected from the Mount Whyte formation, which he considered Lower Cambrian, at his locality 62x, in a section on the ridge of Mount Assiniboine extending eastward toward Wonder Pass. In his description, Walcott (1917, p. 68) gave the stratigraphic position merely as "250 feet below the oolitic limestone at the summit of the Mount Whyte formation of the Lower Cambrian." Later (1928, p. 297), he published a measured section of the Lower and Middle Cambrian rocks of the Mount Assiniboine region, from which it is possible to place the occurrence more precisely in the section. Walcott found no other fossils in association with *Gogia*, but he collected a large faunule from his locality 62w about 250 feet above the *Gogia* occurrence. Rasetti (1951, p. 210) has recently referred the fauna of Walcott's locality 62w to his *Plagiura-Kochaspis* zone of the Middle Cambrian. According to Walcott's section, the *Gogia* occurrence is 430 feet above the highest *Olenellus* fauna.

The age of the Mount Whyte formation has given rise to some confusion and several writers have continued to refer it to the Lower Cambrian, largely because the lowest beds contain unquestionable Lower Cambrian fossils. Burling (1916, p. 471) expressed the opinion that all but the lowest beds of the Mount Whyte were Middle Cambrian, and his conclusions have been confirmed in recent years by Deiss (1940) and Rasetti (1951).

Rasetti placed the Lower Cambrian-Middle Cambrian boundary in the lower part of the Mount Whyte formation of previous workers. He, accordingly, restricted the name Mount Whyte to those beds above this boundary, and referred the Lower Cambrian portion of the old Mount Whyte to the top of the St. Piran formation. Rasetti's usage is adopted in this paper. It seems clear from Walcott's section that the type locality of *Gogia* lies within the upper middle part of the beds which he included

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EXPLANATION OF PLATE 40

FIGS. *1–5*—*Gogia prolifica* Walcott. *1*, *2*, parts of brachioles, showing cover plates, G.S.C. Cat. No. 10088a, ×5; *3*, proximal ends of four brachioles, showing outer surface and zig-zag suture, G.S.C. Cat. No. 10088b, ×3; *4*, *5*, entire specimens, G.S.C. Cat. No. 10088a–b, natural size. (p. 286)

in the Mount Whyte, and it, therefore, is believed to lie within the Mount Whyte formation as restricted by Rasetti. It seems impossible, without further field work, to determine whether Walcott's *Gogia* locality should be referred to the *Wenkchemia-Stephenaspis* zone, Rasetti's lowest Middle Cambrian zone, or to the overlying *Plagiura-Kochaspis* zone, to which the beds 250 feet above it belong. However, it seems safe to regard these beds as of early Middle Cambrian age.

The new *Gogia* occurrence, which this paper describes, is on the eastern slope of Mount Kitchener, Alberta, above the Dome Glacier, at an elevation of about 7500 feet, situated about 120 miles northwest along the continental divide from Walcott's locality. The find is of special stratigraphic interest because here *Gogia* occurs in somewhat younger rocks.

Gogia occurs in the upper part of a sequence of about 250 feet of thin-bedded, fine-grained, bluish-gray, buff-weathering, shaly limestone, associated with the following fauna:

Zacanthoides planifrons Rasetti
Kootenia burgessensis Resser
Elrathina cordillerae (Rominger)
Elrathia permulta (Walcott)
Glyphaspis cf. *G. parkensis* Rasetti
Acrothele sp.
Hyolithes sp.

This assemblage clearly belongs to the *Bathyuriscus-Elrathina* zone (Rasetti, 1951, p. 99), and is, accordingly, of the same age as the Stephen formation of the area farther southeast. The lower beds of the sequence contain a species of *Glossopleura*, and probably belong to the *Glossopleura* zone below the *Bathyuriscus-Elrathina* zone.

SYSTEMATIC DESCRIPTION

GOGIA PROLIFICA Walcott, 1917
Plate 40, figs. 1–5.

Gogia prolifica WALCOTT, 1917, Smithsonian Misc. Coll., 67, no. 3, p. 68, pl. 8, figs. 1, 1a–b.

Description.—Calyx flattened conical, consisting of a large number of irregular polygonal plates. Plates in oral region mainly small and lacking definite arrangement, becoming larger in the lower part of calyx where there is some tendency towards a more regular pattern. Margins of larger plates irregularly folded and crenulate, folds running at right angles to the sutures. Thecal pores lacking. Stem imperfectly seen, probably consisting of relatively large, irregular plates. Calyx surmounted by nine or more long, slender, rounded brachioles springing from a complex arrangement of small plates in the oral region. Exact mode of articulation with the calyx obscure. Brachioles consisting of a large number of regular small plates, arranged biserially and meeting to form an even, zig-zag suture. Suture covered on the inner surface by a double row of small cover-plates, each cover-plate being about half the size of the arm plates. Brachioles tapering slightly, distal ends not seen.

Material.—Eight specimens, G.S.C. Cat. No. 10088 a-h.

Discussion.—Several of the specimens show fairly well preserved structures in calcite; in others the calcite has been removed by solution and, as in Walcott's original material the skeletal elements are only imperfectly preserved as casts.

There can be little doubt as to the identity of these specimens with Walcott's species. Walcott did not, however, mention the presence of cover-plates on the brachioles, but presumably his specimens were not sufficiently well-preserved to show these fine structures.

Gogia prolifica bears some resemblance to the form described as *Eocystites ? longidactylus* by Walcott (1886, p. 94) from the Middle Cambrian of Nevada and elsewhere. It appears to differ mainly in the lack of thecal pores along the sutures between the plates of the calyx. Walcott mentions short pinnulae preserved as casts associated with some of the arms in this species; it is just possible that these are remnants of some form of cover-plate system, but if so they are much larger than those shown to be present on the arms of *Gogia prolifica*. The brachioles, with their cover-plates, are similar to those of *Macrocystella mariae* Callaway which occurs in beds of Tremadoc age in the Welsh borderland, but this form, as figured by Bather (1900, p. 56) shows a much higher degree of organization than *Gogia* and properly belongs to the true Cystoidea.

CLASSIFICATION

There has been considerable discussion over the systematic position of the early pelmatozoans. Bather (1900, p. 48) proposed the family Eocystidae to include some of the obscure Lower and Middle Cambrian forms from England and North America, such as *Eocystis* Billings and *Protocystis* Hicks. He considered that they could not well be distinguished from *Eocystites ? longidactylus* Walcott, and since this form was the most completely known of the group, he took it as the example of the family and gave a brief diagnosis. He regarded the family to be intermediate between the Amphoridea and Rhombifera.

Jaekel (1918, p. 24) thought *Eocystites ? longidactylus* Walcott had crinoidal affinities and he made it the genotype of *Eocrinus*. He considered that most of the genera of Bather's Eocystidae belonged to the Crinoidea and he included them in his sub-class Eocrinoidea under the family Eocrinidae. Fedotov (1934, p. 241) did not give either the Eocystidae or Eocrinidae a definite place in his scheme of classification as he felt that the material on which these families were based was too incomplete for their affinities or systematic position to be established with any precision. He listed the genera *Eocystis* Billings, *Gogia* Walcott, *Protocystis* Hicks, *?Cigara* Barrande, and *Ascocystis* Barrande (emend Jaekel) under the family Aristocystidae Neumayr without comment. In the classification proposed by Bassler in 1938, these genera are placed in the Cystoidea under the new family Eocystoidea of the Order Amphoridea. Bassler did, however, add a rider that this was an introductory family which included primitive cystids and crinoids (Bassler, 1938, p. 8). The most recent reclassification of the Pelmatozoa is by Regnell (1945, p. 14 et seq.). His arrangement differs from that of Bassler. He retains the Eocrinoidea of Jaekel but he elevates it to class rank and gives it equal status with the Crinoidea.

It seems beyond reasonable doubt that *Gogia* should be regarded as a typical member of the Eocrinoidea. The nonpinnulate, biserial arms are typical of the blastoids and cystoids, but the lack of thecal pores suggests that the genus is not closely related to either of these two groups. The presence of cover-plates is perhaps a more crinoid-like feature, but they are known to occur in several cystoid genera (Jaekel, 1899, p. 88) and have already been mentioned in the case of *Macrocystella*. Bather (1900, p. 56) believed the Macrocystellidae to be directly descended from his Eocystidae and the presence of cover-plates in *Gogia* tends to support this view. The irregular plates and plating structure are primitive and the marked crenulation of the plate margins at right angles to the sutures may also be a primitive feature. Bather (1914, p. 426) considered that such folds may have later given rise to the pectinirhombs in the true cystoids. The structures shown by *Gogia* lend support to an independent position for the Eocrinoidea and suggest that the group was ancestral to both the Cystoidea and to the Crinoidea.

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JOURNAL OF PALEONTOLOGY, VOL. 27, NO. 2, PP. 288–295, 3 TEXT FIGS., MARCH 1953

PALEONTOLOGICAL NOTES

A NEW EDRIOASTEROID FROM THE CARBONIFEROUS OF ALBERTA[1]

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INTRODUCTION

During the course of field work on the Carboniferous system in the Alberta Rockies, a single, well preserved edrioasteroid was found in the upper part of the Banff formation, near Jasper, Alberta. The specimen is the first reported occurrence of an edrioasteroid from the Carboniferous of western Canada; it is described in this note as a new species and is assigned to the genus *Agelacrinites*.

The specimen was taken from Morro Creek, which lies just south of the Jasper-Edmonton highway, about 10 miles north of Jasper. Morro Creek cuts directly across the strike of a steeply dipping Devonian-Carboniferous sequence in which a total thickness of 640 feet of the Banff formation is well exposed.

FIG. 1—*Agelacrinites jasperensis* Harker, n. sp. Holotype, ×5.

The Banff formation is the lowest of the Carboniferous formations in the Alberta Rocky Mountains. It corresponds lithologically and stratigraphically with the Lodgepole limestone of Montana (Collier and Cathcart, 1922, p. 173) and is, in part at least, of the same age. The Banff formation is abundantly fossiliferous at some localities, and its fauna contains both Kinderhook and Osage elements. Exact correlation with the Mississippian of the Mid-Continent area is difficult since many species appear to have occurred earlier in the Cordillera. There seems little doubt, however, that strata of Kinderhook and Osage age are represented in the Banff formation.

The fauna associated with the edrioasteroid includes the following species:

Leptaena analoga (Phillips)
Schellwienella inequalis (Hall)
Dictyoclostus jasperensis (Warren)
Dictyoclostus arcuatus (Hall)
Dictyoclostus sp. cf. *D. altonensis* (Norwood and Pratten)
Linoproductus ovatus (Hall)
Productella sp.
Rhynchotetra, n. sp.
Spirifer missouriensis Swallow
Spirifer albertensis Warren
Spirifer sp. cf. *S. rowleyi* Weller
Platyrachella? rutherfordi (Warren)
Punctospirifer subtexta (White)
Cleiothyridina lata Shimer
Composita sp.
Dielasma chouteauensis Weller

SYSTEMATIC DESCRIPTION

Class EDRIOASTEROIDEA
Family AGELACRINITIDAE Bassler, 1935
Genus AGELACRINITES Vanuxem, 1842
AGELACRINITES JASPERENSIS Harker, n. sp.
Figure 1

Diagnosis.—Agelacrinitid with simple plating arrangement and anal pyramid of seven plates close to periphery.

Material.—Holotype, Geol. Surv. Canada No. 10051, from upper part of Banff formation, 135 feet below Banff-Rundle contact, Morro Creek, Jasper, Alberta. G.S.C. locality 18559.

Description.—Test circular, oral surface

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flattened, interambulacral areas depressed. Interambulacral plates smooth, polygonal, few in number and forming an irregular mosaic. Anal pyramid of seven plates forming a low cone near to the periphery, slightly crushed and partly obscured by the imbricating inner wall of the periphery. Ambulacra five in number, stout and curved distally, 1–3 curving clockwise, 4 and 5 counter-clockwise; two rows of alternating cover-plates meeting medially to form a zig-zag suture. Cover-plates gradually diminishing in size distally but without alternation of large and small plates. Structure of peristomial region insufficiently preserved for interpretation. Adoral surface bounded by a low peripheral wall consisting of an inner ring of large imbricating plates and four outer rings of smaller plates. Diameter of holotype, 7.0 mm.

Remarks.—The genus *Agelacrinites* has a reported range from Devonian to Mississippian. The new species, *Agelacrinites jasperensis* resembles the genotype, *Agelacrinites hamiltonensis* Vanuxem in those features regarded by Bassler (1935, pp. 1–2) as being of generic significance. Of the Mississippian species, it differs from *Agelacrinites legrandensis* Miller and Gurley in having a simpler plating structure and having the anus set closer to the periphery. It bears some resemblance to *Agelacrinites blairi* Miller, but differs in the position of the anus and the degree of curvature of the arms.

The arrangement of plates is remarkably simple considering the late stratigraphic position within the range of the edrioasteroids. The other Mississippian species of *Agelacrinites* have many more plates, and other upper Paleozoic genera such as *Discocystites*, *Lepidodiscus* and *Ulrichidiscus* show an even greater complexity of structure.

Occurrence.—The species is based on a single specimen and is only known from the upper part of the Banff formation, Morro Creek, Jasper, Alberta, Canada.

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MICROPALEONTOLOGY OF THE BRANDON LIGNITE, AN EARLY TERTIARY COAL IN CENTRAL VERMONT: PRELIMINARY NOTE

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The Brandon lignite is a small deposit of low rank coal[1] occurring near the village of Forestdale three miles northeast of the town of Brandon, Vermont (fig. 1, see inset map, lower right). The lignite is found in association with formerly locally important iron and manganese ores, ochers, sands and clays. The deposit has attracted considerable scientific interest since its discovery in the nineteenth century, both because of the unusual abundance of fossils in the sediments, and, perhaps more especially, because of the rarity of fuel deposits of economic value in New England. Few of the questions raised by the geologic occurrence of the deposit and its paleontological significance had been answered, however, until recent investigations based on new collections and extensive field study were completed. A coördinated program has been directed toward geologic interpretation of the deposit, petrographic study of the coal and varied phases of its paleobotanical study (Barghoorn and Spackman, 1949,

[1] Because it is relatively unconsolidated, has a relatively low B.T.U. rating and is brown when dry, the Brandon deposit might better have been called a brown coal. However, because degree of consolidation is difficult to measure, because no exact definition of brown coal and lignite exists, and because of usage, the term lignite, in its general sense, can be retained.

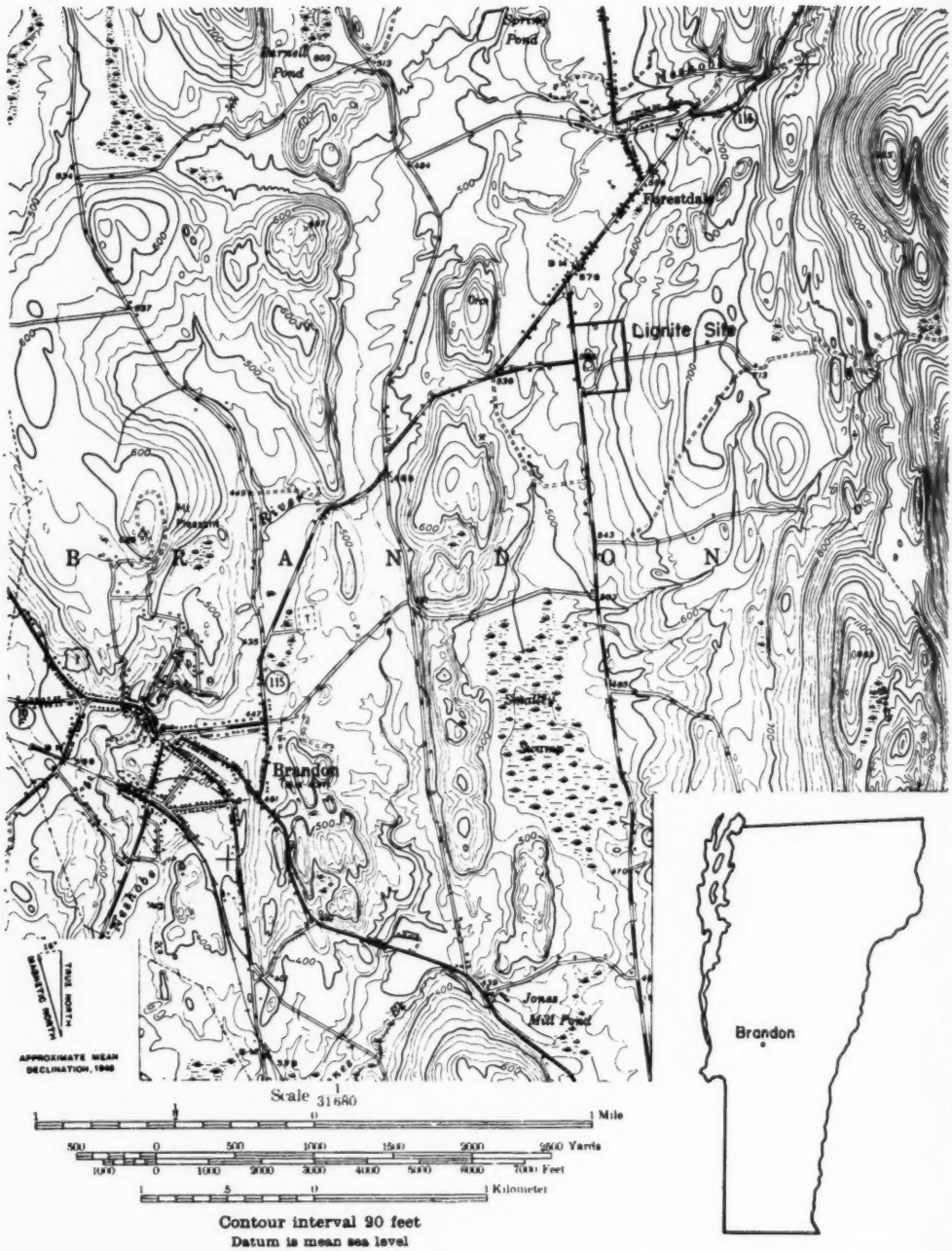

FIG. *1*—Map showing location of Brandon lignite deposit.

1950). The following discussion summarizes briefly the results of intensive study of the plant microfossils occurring in the Brandon lignite. It seems desirable to summarize these results at this time, pending publication of the monographic study of pollen and spore types and it is particularly desirable to make a brief appraisal of the paleoecological significance of the Brandon deposit in view of our present meager knowledge of environmental conditions during the early Tertiary of northeastern North America.

Tertiary pollen and spores have received very little attention by American paleobotanists, and have been systematically investigated by European paleobotanists only during the last two decades. Some students regard the difficulty of botanical determination as nearly insuperable and have proposed taxonomically artificial systems of description and nomenclature. Others emphasize that botanical determinations *can* be made and must be as accurate as possible if the significance of the past occurrences of living genera are to have any real meaning, either botanically or geologically. Knowledge of the identity of macroscopic remains in a sediment and understanding of the geologic evidence greatly aid the pollen analyst in his identifications. The writers strongly support this thesis and view as inadequate the description of pollen and spores which makes no reference to megafossils and the sedimentary structures with which the microfossils are associated. The authors feel that conclusions resulting from study of the microfossils in the Brandon lignite might help solve problems in the paleoecology of the deposit, and that these results should necessarily be coördinated with other phases of paleobotanical study of this sediment. In this way various lines of botanical evidence have been interrelated in developing an ecological concept provided by the varied fossil groups represented.

A large proportion of Tertiary plants are referable to existing genera and families, and botanical determination of fossil pollen and spores, in terms of these living entities, is desirable if palynological research on Tertiary sediments is to have any meaning beyond static description of microfossils for purely stratigraphic purposes, however useful these may be. In order to approach the problem of botanical determination of pollen and spores in the Brandon deposit a reference collection of extant forms was initiated. The pollen and spore collection was in part determined by knowledge of the facts that the megafossil flora is composed entirely of dicotyledonous plants, almost exclusively woody forms, and that the flora has its closest affinities in the modern North American vegetation with that of the southeastern and Gulf coastal states and is most probably of middle or early Tertiary age.

Flowers, floral buds or stamens of approximately 1000 species of vascular plants were collected from herbarium specimens[2] in preparation of a reference collection. The samples were acetylated, using a modification of Erdtman's technique (1943). This procedure frees the pollen and spore coats from extraneous carbohydrate fractions of the floral parts and likewise almost always removes the contents of the pollen grains. Permanent preparations of the pollen and spores were secured by the use of sealed glycerin-jelly mounts. The reference collection was carefully studied and the information so acquired was organized by means of an index card file to facilitate identification of fossil forms.

Samples of the sediments for micropaleontological study were collected from selected levels of the deposits. These were treated by demineralization, maceration, bleaching, and acetylation in order to free the pollen and spore coats from other substances and to yield microfossils comparable in physical condition to the pollen and spores of living forms in the reference collection.

Seventy-six discrete entities of pollen and spores and two other important microfossils have been determined. These are the distinct, well-marked entities. Fragmentary, poorly preserved and extremely rare forms are not included. The total includes the pollen of *Pinus*, *Glyptostrobus*, members of the Gramineae and forty-six generic entities of dicotyledonous plants. Of the dicotyledonous genera, 32.6 per cent are native to the modern flora of Vermont. This percent-

[2] Made available for study through the courtesy of the Gray Herbarium and the herbarium of the Arnold Arboretum of Harvard University.

age is almost identical with that calculated for the much smaller, previously known total flora based on megafossils, chiefly wood, fruits and seeds. The pollen flora includes most of the genera found in the macroscopic remains. This percentage of genera, now native to the region of the fossil deposit, places the flora within the range upper Oligocene to lower Miocene based on a proposed curve showing percentage composition of Tertiary floras (Barghoorn, 1951). This curve cannot, of course, be expected to yield more than an approximate date for a flora of unknown age, though the agreement of evidence in this case is of much interest.

As noted, the Brandon lignite flora finds its closest existing counterpart in the vegetation of the southeastern United States. Several of the groups of plants first shown to be present by pollen studies intensify the subtropical and exotic aspects of the flora, and hence, on paleoecological grounds, increase the likelihood of Oligocene age for the deposit. These forms include *Glyptostrobus*, a genus of the Taxodiaceae comprising the ecological equivalent, in southeast China, of the southeastern American *Taxodium*. Abundant specimens of leaves and twigs determined as *Glyptostrobus* are reported from the Eocene Wilcox flora of the Mississippi embayment (Berry, 1930). Other forms of ecological significance include *Jussiaea*, a genus of the Onagraceae now distributed chiefly in wet environments of the tropics and subtropics; *Engelhardtia*, a genus of the Juglandaceae of subtropical and southeastern Asiatic distribution in the modern flora; *Planera* of the Ulmaceae and *Liquidambar* of the Hamamelidaceae, both indicators of warm temperature or subtropical climate and moist to swampy conditions. Most interesting of all was the discovery of pollen in the *Mimusops* group of the family Sapotaceae, representatives of which, in the United States, are now confined to southern Florida. Well preserved fruits and wood of this group are also abundant in the deposit and, indeed, were recognized, taxonomically, as a result of the clues provided by identification of the pollen.

Comparison of the Brandon flora with modern plant communities or associations in the southern states indicates the nearest equivalent to be the vegetation of the "bays" and other nonalluvial swamps[3] of northern, central and western Florida. The majority of the important genera of the Brandon pollen flora are found today in the Florida swamps. There are, however, several important respects in which the Brandon assemblage differs from the modern swamp floras of Florida, and these differences, in terms of paleoecological reasoning, argue for an early Tertiary age of the deposit. These indicators may be outlined as follows.

1. The Brandon flora is composed almost entirely of dicotyledonous woody plants, whereas monocotyledonous and dicotyledonous herbs are significantly common in the flora of present-day Florida swamps.

2. The genus *Pinus* is relatively uncommon in the lignite, whereas it is abundantly represented in the microfossils of peat from the modern equivalent swamps.

3. *Taxodium*, often common in existing swamps, is absent in the Brandon flora, though represented by an ecological equivalent, the genus *Glyptostrobus*, of southern China.

4. Representatives of the *Mimusops*, group of the family Sapotaceae are absent in the present southeastern swamps and do not now occur indigenously north of the essentially tropical region of lower peninsular Florida.

These diverse factors are indicative of both pronounced biotic and climatic divergence from the modern flora and climate of northern New England. They are especially indicative of unusually warm climate for the latitude of the north temperate United States. In terms of the overall paleoecologic concept of Tertiary climates such divergences are here regarded as indicating the early Tertiary age of the Brandon sediments.

A survey of the composition of the pollen

[3] The term "nonalluvial swamp" refers to basins of organic deposition existing in poorly drained topography. Such basins, often of considerable areal extent, are usually free of inundation by flood-plain deposits and hence their deposits are almost entirely organic, primarily of plant origin. Alluvial swamps, on the other hand, are developed on seasonally flooded land adjacent to major drainage basins. The flora and ecological conditions of these two major swamp types of the coastal plain are quite divergent.

flora in the several parts of the deposit supports the interpretation that the underlying lignitic sands were deposited during a phase of rapidly eroding streams carrying sediment into a small basin in a Tertiary valley of central Vermont. The subsequent organic sediments, now represented by the lignite, were deposited in a swamp with fluctuating edaphic conditions, apparently trending from rapid sedimentation, with abundant clastics, to slow deposition resulting in relatively unstratified organic attritus. The lignite is overlain by an organic silt representing, presumably, the sedimentary record of the flood plain of a sluggish river. Present relationship between the lignite and silt is greatly disturbed by subsequent small-scale geologic deformation. Pollen of *Cyrilla* and of *Gordonia* (the tyty and loblolly bay, respectively, of modern southern swamps) is abundant in the lignite but absent in the silt. Both of these woody forms today are quite well restricted to nonalluvial swamps with consistently high water levels, and fail to maintain themselves in silting basins of deposition. Pollen of *Quercus* is very much more abundant in the silt than in the lignite. Within the lignite itself there are considerable fluctuations in percentages of different species or genera represented by pollen. For example, the percentages of *Cyrilla* and *Quercus* pollen are in a nearly reciprocal relationship. Increases in *Cyrilla* and the concomitant decrease of *Quercus* presumably mean deeper water in the swamp. Although the silt shows a microfossil content different from that of the lignite, there is a continuity and similarity of flora to indicate that the silt is part of the same sedimentary sequence as the lignite.

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AN ABERRANT NAUTILOID OF THE TIMOR PERMIAN

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In his excellent report on the Permian cephalopods of Timor, Haniel (1915, pp. 132–134, pl. 55, figs. 3a-3c) described a very distinctive species of nautiloids and proposed for it the name *Nautilus* (*Aganides*) *bitauniensis*. He based this species on three specimens from the type locality of the Bitauni beds. Those strata have yielded a cephalopod fauna that is amazingly like that of the American Leonardian, on the opposite side of the world. Therefore, it might well be expected that forms related to Haniel's species would be found here. However, none has so far been located in the western hemisphere, in spite of the fact that a great deal of work has been done on our Permian nautiloids, and the Leonard and equivalent American formations have yielded a large and varied cephalopod fauna.

The scope of the genus *Nautilus* has come to be greatly restricted. Furthermore, as Schindewolf (1923, pp. 325-328) and others have shown, it is not possible to determine the affinities of the type of *Aganides;* therefore, that genus, though quite valid, is not usable, for one can not ascertain what forms should be referred to it. Because of these facts, Haniel's species can no longer be placed in either *Nautilus* or *Aganides*, and in order that we might determine its generic relationships, we requested the loan of the figured syntype, which was kindly made available to us by Dr. W. Bierther of the University of Bonn.

Clearly this form is not close to any of the numerous nautiloids now known from the late Paleozoic, but as Haniel pointed out it is indeed similar to *Nautilus geinitzi* Oppel of the Upper Jurassic of Moravia and possibly Silesia and southern France (see Zittel, 1868, p. 45–46, pl. 2, figs. 1–7; and Pictet, 1867, pp. 63–65, pl. 2, figs. 1a–2b). Both of these species have subdiscoidal nautiliconic conchs, rather small umbilici, siphuncles located fairly close to the venter, and sutures that consist of eight lobes (the larger of which are V-shaped) and eight rounded saddles. They seem to differ materially only in that the one from Timor has a somewhat broader conch which is distinctly flattened ventrally. Even the slight differences indicated by the accompanying suture drawings may well be due in part to variations in interpretation, stage of ontogenetic development represented, etc.

Long ago Meek (1868, p. 491) established *Pseudonautilus* with *N. geinitzi* as type, and the validity of that genus was recognized by Spath (1927, p. 22) who indicated that it is limited to the Upper Jurassic. Insofar as we have been able to ascertain, no closely similar forms are known that are intermediate in age between Oppel's and Haniel's species; and the beds which yielded them are so very far apart stratigraphically that it seems reasonable to conclude that the two represent completely independent developments and should therefore not be regarded as congeneric. We have been very reluctant to follow this matter to what appears to be its logical conclusion. Accordingly we have given it exceedingly careful and lengthy consideration and have discussed it with other students of cephalopods (especially Bern-

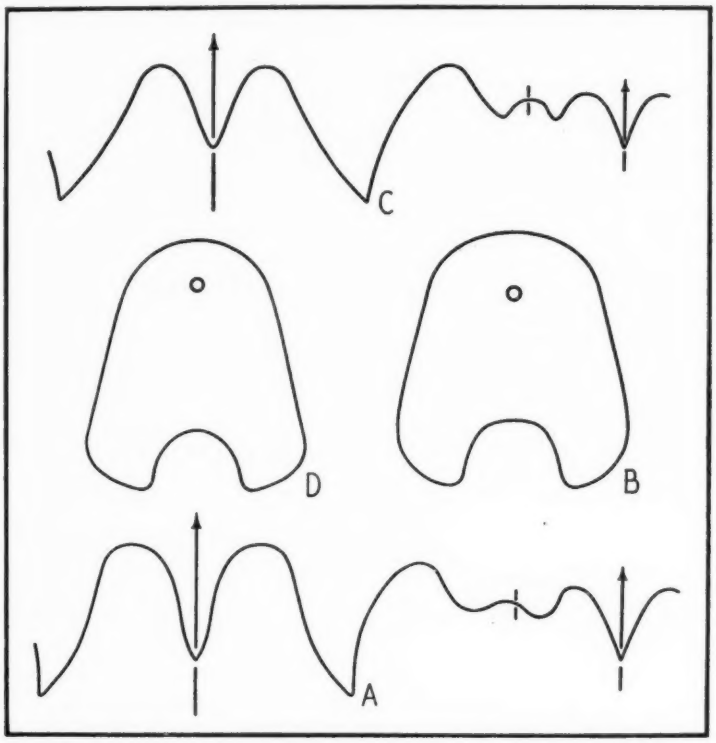

FIG. 1—Diagrammatic representations of sutures and cross sections of *Permoceras bitaunienese* (Haniel) [A, B] and *Pseudonautilus geinitzi* (Oppel) [C, D], all ×1. The first two are based on the adoral portion of Haniel's figured syntype; the others are adapted from Zittel.

hard Kummel and Curt Teichert). All are agreed that this case should be regarded as an example of homeomorphy. Therefore, it is here proposed that Haniel's species be made the type of a new genus, **Permoceras,** which in morphology is not known to differ significantly from typical *Pseudonautilus*. Presumably it arose from the Domatoceratidae, but its sutures are so much more "advanced" than are those of any other Permian nautiloid genus that it should be regarded as constituting a monotypic family, the **Permoceratidae.**

It should probably be mentioned that Zittel (1868, p. 45) after studying the type specimens of both *N. geinitzi* Oppel and *N. aturoides* Pictet concluded that they are conspecific, but the published illustrations of them do not seem to us to substantiate that belief. The French Jurassic forms *N. malbosi* and *N. dumasi*, both of Pictet (1867, pp. 60–62, pl. 9, figs. 2a–3; pl. 10, figs. 2a–2c) may possibly belong in *Pseudonautilus* but their sutures are simpler than those of the type species. *Aganides kochi* Prinz (1906, pp. 230–231, pl. 3, fig. 2) of the Jurassic of central Europe and possibly France is now the genotype of *Hercoglossoceras* Spath (1927, p. 22).

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JOURNAL OF PALEONTOLOGY, VOL. 27, NO. 2, P. 296, MARCH 1953

NOMENCLATURAL NOTES

A NEW RADIOLARIAN GENUS

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Haeckel (1882, p. 430) named *Dictyoprora* and characterized it as having a free apical chamber. In his *Challenger* Report (1887, p. 1250) Haeckel placed this genus as a subgenus of *Sethamphora*. He further, in the same monograph (p. 1305) used *Dictyoprora* as a subgenus of Ehrenberg's 1860 genus *Dictyocephalus* and distinguished it as having an oral collar. It is clear that Haeckel's second use of the name is incorrect and that this homonym requires a new name. For this subgenus I propose herein the substitution of the new name *Streptodelus* (Greek, clear or evident collar). The oral collar at once distinguishes the newly named subgenus from the typical subgenus which lacks a collar. The type species selected is *Dictyocephalus amphora* Haeckel, 1887, the first species included by that author in the *Challenger* monograph. This species is found in the central Pacific but there are numerous others in the Eocene of Barbados, and California as well as elsewhere. At least one species occurs in the Upper Cretaceous of California.

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A REPORT ON BIOLOGICAL ABSTRACTS

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In 1950 Professor Ben F. Howell, who had served as Editor of the Paleozoology section of Biological Abstracts for 25 years, from its inception and through years of great financial difficulty, indicated that he wished to relinquish the task. The Editors of the Abstracts consulted the Secretary of the Paleontological Society, and eventually I was asked to assume this responsibility. I did so, and have considered my work for the Abstracts as being on behalf of my fellow paleontologists. It is now two years since I took over this editorship, and I think a report on the progress of the work may be due you.

In 1950 I was skeptical about the value of the Abstracts, and doubtful whether it was worth supporting, but I felt that I should try for two years to see what could be done to improve coverage and make it a really useful tool for working paleontologists. Cooperation from the editorial office in Philadelphia was whole-hearted, and I can now report that the great majority of papers dealing with any phase of paleozoology are being abstracted, and are appearing fairly promptly. Particular attention has been paid to Russian and other East European journals which most workers do not see.

During 1952 Biological Abstracts printed summaries of over 1800 papers in paleozoology. My responsibility does not extend to paleobotany, so that my figures are less reliable, but something over 200 papers in that field were also abstracted. I think any record of over two thousand papers abstracted in a single year is a good and useful one. As users of the Abstracts will have noticed, these are not all strictly current papers. When I took over as editor many papers dated 1948 were still coming into our libraries, and that year was taken as a datum, beyond which I hope to see the Abstracts complete in our field. So this total of 2000 includes some papers as much as four years old, but it also includes many papers within six months of their original issue.

Much remains to be done, but we can already say that a reader of the Abstracts will find references to almost all major papers in paleozoology, with all new genera and species, and indication of the scope of faunal lists. Several correspondents have commented on the labor involved in preparing abstracts, but actually the headaches do not lie there, but in trying to keep track of the literature. Colleagues could be of great service by seeing that copies of journals, museum or university publications which they distribute get sent to the Abstracts. We will catch them sooner or later, but sooner is more useful to all.

As most biologists know, Biological Abstracts is a cooperative enterprise. With the exception of a handful of fulltime workers in Philadelphia (and I have been impressed by the amount of work that gets done by so few) all abstracting and editing is done by volunteers, willing to work to serve their science. In spite of this, the cost of processing and printing almost 40,000 abstracts a year (there were 37,357 in 1952) is great. Apart from a few small grants from societies and industries, this cost must be met by sale of the Abstracts. Section E, which contains all abstracts in zoology, including paleozoology, is available at $6.00 a year, a price at which all Geology Departments, and many individual paleontologists could afford to subscribe. I think if they will examine recent issues they will think it worth subscribing. If your library does not get the Abstracts, specimen copies of section E may be obtained from the Abstracts office in Philadelphia, or from me.

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ERRATA

In an earlier paper the writer (Campbell, 1951, New genera and subgenera of Radiolaria, Jour. Paleontology, vol. 25, pp. 527–530) proposed a new generic name, *Thalassoraphis*, for a recent thalassospherid radiolarian. This name is incorrectly derived and consequently is herewith corrected to *Thalassorrhaphis* in accord with the rules of word composition in Greek.

MICROFAUNA OF THE PENNSYLVANIAN GLEN EYRIE FORMATION, COLORADO: CORRECTIONS

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Dr. Henry V. Howe has kindly called my attention to nomenclatural errors in my description of the Glen Eyrie fauna (Jour. Paleontology, vol. 26, pp. 613–621, pls. 81–82, 1952).

Healdia unispinosa McLaughlin, 1952, (p. 617) is a junior homonym of *Healdia unispinosa* Hamilton, 1942, (Jour. Paleontology, vol. 16, p. 717, pl. 110, fig. 3) (Permian, Texas). *Healdia clavis* is hereby proposed as a new name for the Pennsylvanian Glen Eyrie species. *Healdia unispinosa* Hamilton is quite similar to the Glen Eyrie species in size and form ratio, but possesses a prominent posterior shoulder and strong overlap by the left valve.

Amphissites robustus radiatus McLaughlin, 1952, (p. 618) is preoccupied by *Amphissites radiatus* (Jones and Kirkby) in Latham, 1932, "Scottish Carboniferous Ostracoda" (Trans. Royal Soc. Edinburgh, vol. 57, part 2, p. 371, text-fig. 18.) *Amphissites radiatus* (Jones & Kirkby) differs from the Glen Eyrie specimen in development of a heavy median lobe, in restriction of radiating ribs to the frill, and in smaller length-height form ratio. *Amphissites robustus flabelluli* is proposed as a new name for the Glen Eyrie subspecies.

Geisina arcuata (Bean) in McLaughlin, 1952, (p. 615) should have appeared as *Limnoprimitia arcuata* (Bean). Kummerow (1949, p. 48) made *Geisina arcuata* (Bean) the genotype of the new genus *Limnoprimitia* ("Ueber einige Süsswasser-ostracoden des Ruhrkohlengebietes," Neues Jahrbuch Abteilung Beilage Band, p. 45–49, 1 fig., 2 pls.).

An additional correction should be made on page 620 (McLaughlin, 1952) in the explanation of plate 82. Figures 21–25 are right valves rather than left valves.

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Gilbert, Orrin W.
Van Nuys—
Slosson, James E.
Ventura—
Carson, Carlton M.
Cook, Theodore D.
Holzman, Johnston E.
Smith, Bernice Young
Whittier—
Braislin, Dana B., Jr.
Darrow, Richard Lee
Leith, Carlton J.
Riccio, Joseph F.

COLORADO

Boulder—
Chronic, John

Thompson, Warren O.
Toepelman, Walter C.
Denver—
Bass, N. Wood
Bramlette, W. A.
Connolly, Frank T.
Crowley, A. J.
Downs, George R.
Gilluly, James
Mielenz, Richard C.
Rezak, Richard
Taylor, Jane M.
Golden—
Johnson, J. Harlan
LeRoy, Leslie W.
Mateer, Warren D.
Grand Junction—
Cadigan, Robert A.
Knight, Raymond L.
Weir, Gordon W.
Williams, George A.
Lafayette—
Moore, Fred E.
Longmont—
Hayes, John R.

CONNECTICUT

Middletown—
Lehmann, Elroy Paul
Milford—
Dunham, Robert J.
New Haven—
Davis, Stanley N.
Dunbar, Carl O.
Storrs—
Tasch, Paul

DISTRICT OF COLUMBIA

Washington—
Applin, Esther R.
Bassler, R. S.
Bates, Charles C.
Boardman, Richard S.
Carroll, Dorothy
Chappars, Michael S.
Cobban, William A.
Cohee, George V.
Cooper, Chalmer L.
Dante, John Henry
Finley, Emmett A.
Gardner, Julia
Gordon, MacKenzie, Jr.
Hawkins, Harold H.
Henbest, Lloyd G.
Knight, J. Brookes
Loeblich, Alfred R., Jr.
Manger, G. E.
Miser, Hugh D.
Nicol, David
Page, Lou Williams
Payne, Thomas G.
Rubey, William W.
Schmidt, Ruth A. M.
Sohn, I. G.
Williams, James Steele
Williams, John R.
Wrather, W. E.

FLORIDA

Coral Gables—
Olsson, A. A.
Orlando—
Richards, J. T.
Twenhofel, W. H.
Plant City—
Cathcart, James B.
Quincy—
Stoever, Edward C., Jr.
Sarasota—
Gould, Howard R.
Tallahassee—
Caldwell, Eleanor T.
Jordan, Louise
Puri, Harbans Singh
Raasch, Albert C., Jr.

GEORGIA

Marietta—
Johnson, Wendell B.

IDAHO

Boise—
Mills, John H.

ILLINOIS

Champaign—
Hopkins, M. E.
Johnson, Robert Britten
Cherry—
Kraye, Robert Frank
Chicago—
Cooley, Douglas R.
Eisenberg, Marvin
Emiliani, Cesare
Gibson, Lee B.
Kawakami, Noboru
Koucky, Frank Louis, Jr.
Krinsley, David H.
Otto, George H.
Seltin, Richard J.
Sloan, Robert Evan
Thomas, Norman L.
Weller, J. Marvin
Winterbotham, John R., III
Effingham—
Bristol, Hubert M.
Evanston—
Dapples, Edward C.
Krumbein, William C.
Sloss, Laurence L.
Herscher—
Clark, William R.
Mattoon—
Ellinwood, H. L.
Mt. Vernon—
Brehm, Clarence E.
Olney—
Nuttall, Brandon D.
Rosiclare—
Sutton, A. H.
Salem—
Allison, James M.
Hockman, James N.
Urbana—
Brockhouse, Robert T.
Hough, Jack Luin
Raasch, Gilbert O.
Scott, Harold W.
Shepps, Vincent C.
Wanless, Harold R.
Wilson, George M.

INDIANA

Bloomington—
Galloway, J. J.
Lafayette—
Serviss, Fred L.
Notre Dame—
Gutschick, Raymond C.

IOWA

Ames—
Hussey, Keith M.
Brandon—
Stainbrook, Merrill A.
Iowa City—
Jeffords, Russell M.
Miller, A. K.
Tester, Allen C.

KANSAS

Independence—
Studt, Charles W.
Lawrence—
Batchelor, Jo Wolter
Fay, Robert O.
Frye, John C
Hattin, Donald E.
Ireland, Hubert A.
King, Ralph H.
Lalicker, Cecil G.
Moore, Raymond C.
Swineford, Ada
Manhattan—
Byrne, Frank E.
Wichita—
Blythe, Jack Gordon
Carmody, Robert A.
Koester, Edward A.
Walters, Robert F.

KENTUCKY

Hopkinsville—
Nosow, Edmund

LOUISIANA

Baton Rouge—
Camacho, Enrique
Cheetham, Alan H.
Hessland, Ivar R.
Howe, Henry V.
Macomber, Donald, Jr.
Murray, Grover E.
Oglesby, Woodson R., Jr.
Sribny, Irene H.
Tator, Benjamin A.
West, Jesse William
Zingula, Richard Paul
Harvey—
Smith, Denver J.
Lafayette—
Anderson, Irvin J.
Strachn, Clarence H., Jr.

Varvaro, Gasper Gus
Wiley, Richard A.
Lake Charles—
Clark, Robey H.
Latta, Lee Allen
Morrow, A. Lyndon
Tipsword, Howard Lee
Monroe—
Wilbert, Louis J., Jr.
Morgan City—
Brophy, John Allen
New Orleans—
Akers, Wilburn H.
Braunstein, Jules
Everett, Robert W., Jr.
Seashore, P. T.
Slama, Don C.
Shreveport—
Brown, Dwight M.
Caldwell, Barbara Summerill
Coley, Tyrol B.
Craver, Frank S., Jr.
Hazzard, Roy T.
Henton, John Melvin, Jr.
Hickcox, Charles A.
Moody, Clarence L.
Philpott, Thomas H.
Robinson, Van D.
Stone, Solon W.
Wilson, Ruth B.

MAINE

Millinocket—
Fairley, William M.
Orono—
Trefethen, Joseph M.

MARYLAND

Annapolis—
Powers, Maurice C.
Baltimore—
Pettijohn, F. J.
Bethesda—
Stephenson, Lloyd W.
Chevy Chase—
Ladd, Harry S.
Hyattsville—
Reeside, John B., Jr.
Rockville—
McIntyre, John B.
Suitland—
Berninghausen, William H.

MASSACHUSETTS

Amherst—
Light, Mitchell A.
Sage, Nathaniel McLean, Jr.
Wilson, Leonard R.
Boxboro—
Hartshorn, Joseph H.
Cambridge—
Barghoorn, Elso Sterrenberg
Kummel, Bernhard
Mencher, Ely
Moore, James R., III
Shrock, Robert R.
Stetson, Henry C.
Deerfield—
Rogers, Arthur A.
Northampton—
Shaub, Benjamin M.
Williamstown—
Ramsdell, Robert C.

MICHIGAN

Ann Arbor—
Briggs, Louis I., Jr.
Kellum, Lewis B.
Lattman, Laurence Harold
Taylor, Dwight W.
Detroit—
Sanford, John T.
East Lansing—
Kelly, William A.

MINNESOTA

Minneapolis—
Goldich, Samuel S.
Kraft, John Christian
Swain, Fred M.
Northfield—
Stewart, Duncan

MISSISSIPPI

Jackson—
Adams, Emmett R.
Anderson, Gerald K.
Bilberry, Charles G.
Brown, Charles E.
Karges, Harold E.
Martin, James L., Jr.
Mather, Katharine
Monsour, E. T.
Parsons, W. Frank
Pike, Stuart J.
Laurel—
Hughes, Urban B.
State College—
Pittman, James S., Jr.
University—
Hughes, R. J., Jr.
Shaver, Robert H.

MISSOURI

Columbia—
Keller, W. D.
Peck, Raymond E.
Unklesbay, Athel G.
Ferguson—
Echols, Dorothy Jung
Kansas City—
Greene, Frank C.
Rolla—
Frizzell, Don L.
Higgs, William R.
St. Louis—
Hinchey, Norman S.

MONTANA

Billings—
Darrow, Geo. F.
Richards, Paul W.
Sonnenberg, Frank P.
Bonner—
Campbell, Charles Virgil
Lewistown—
Beekly, Emerson K.
Miles City—
Stewart, Francis

NEBRASKA

Lincoln—
Elias, Maxim K.
Lugn, Alvin L.
Reed, Eugene C.

NEVADA

Las Vegas
Shannon, Ellen C.

NEW JERSEY

Dorchester—
Sangree, John B., Jr.
Emerson—
Klemme, H. Douglas
New Brunswick—
Martens, James H. C.
McMaster, Robert L.
Nine, Ogden W., Jr.
Palisade—
Coryell, Horace N.
Princeton—
Hess, Harry H.
Howell, B. F.
Van Houten, Franklyn B.
Vineland—
Campbell, Robert B.

NEW MEXICO

Albuquerque—
Lovejoy, Bill P.
Smith, Ralph E.
Thorp, Eldon M.
Toomey, Donald F.
Wengerd, Sherman A.
Jal—
Taylor, Warren L.
Roswell—
Meyer, Richard F.
Winkler, Hans
Socorro—
Teichert, Curt

NEW YORK

Bronxville—
Consiglio, Louis A.
Brooklyn—
Wang, Kia-Kang
Buffalo—
Hibbard, Raymond R.
Ithaca—
Palmer, Katherine V. W.
Young, Robert S.
New York—
Eicher, Donald B.
Ellis, Brooks Fleming
Flagler, C. W.
Imbrie, John
Jablonski, Eugene
Jaekel, Julie Anne Klovstad
James, John W.
Johnson, F. W.
Kaufmann, Godfrey F.

Kay, Marshall
King, Robert Evans
Martin, Lewis
Messina, Angelina R.
Newell, Norman D.
Pardo, Georges
Salvador y Diaz, Amos
Sander, Nestor John
Sass, Louis Carl
Schaffel, Simon
Shields, James A.

Pittsford—
Alling, Harold L.

Poughkeepsie—
Johnsen, John H.
Warthin, A. S., Jr.

Rye—
Brixey, Austin Day, Jr.

Syracuse—
Apfel, Earl T.

Troy—
Beers, Roland F.
Lowman, Shepard W.

NORTH DAKOTA

Bismarck—
DeLong, Jack M.
Harris, Steven H.

Fargo—
Pye, Willard D.

Williston—
Doroshenko, Jerry

OHIO

Athens—
Sturgeon, Myron T.

Cincinnati—
Abbott, Ralph E.
Caster, Kenneth E.
Holland, Frank, Jr.
Kerr, S. Duff, Jr.

Columbus—
Frazier, Noah A.
Schopf, James M.
Spieker, Edmund M.
Stewart, Grace Anne
Summerson, Charles H.

Dayton—
Stevenson, Robert E.

Marietta—
Walk, Hugh G.

Oxford—
Martin, Wayne D.
Wade, F. Alton

Springfield—
Baker, Chester E., Jr.

Wooster—
Danner, Wilbert R.
Locker, Walter A., Jr.

OKLAHOMA

Ardmore—
Gill, J. P.
Hicks, I. Curtis
Johnson, William R.
Neustadt, Walter, Jr.
Speer, John Hill
Tomlinson, Charles W
Westheimer, Jerome Max
White, Maynard P.

Bartlesville—
Ewbank, Norman Ware, Jr.
Strimple, H. L.
Weeks, Warren B.

Chickasha—
Bryan, J. Victor

Duncan—
Huff, Jack Newton
Putman, Darrell M.

Enid—
Baker, Vernon R.
Clifton, R. L.
Douglass, Harry Marvin
Muir, J. Lawrence

Muskogee—
Wallace, Maurice H.

Norman—
Branson, Carl C.
Culp, Eugene F.
Decker, Charles E.
Frederickson, Edward A.
Harris, Reginald W.
Huffman, George G.
Lucas, Elmer Lawrence
Moore, Carl A.
Tanner, William F.

Oklahoma City—
Eisner, Stephan M.
Isbell, Grover Jim
Kate, Frederick H.
McGee, Dean A.
Pasquella, George G.
Pollard, Robert T.
Renfro, Kenneth M.
Tubb, George G.
Turk, Lon B.

Okmulgee—
McCulloch, George G.

Shawnee—
Phillips, David Lee

Stilwell—
Hicks, Forrest L.

Tulsa—
Bennison, Allan P.
Branson, Herberta Van Pelt
Curray, Joseph Ross
Denison, A. Rodger
Ellsworth, Elmer W.
Enlows, Harold E.
Goldstein, August, Jr.
Grigsby, R. B.
Harlton, Bruce H.
Hawkins, Glenn D.
Holden, Frederick T.
Kauffman, James S.
Kjellesvig-Waering, Erik N.
Levorsen, A. I.
Porterfield, Robert R.
Reeves, James E.
Rittenhouse, Gordon
Rominger, Joseph Franklin
Ryniker, Charles
Snider, James W.
Travis, Richard
Wagner, Carl D.

OREGON

Corvallis—
Boyd, Harold A., Jr.

Eugene—
Bressler, Calder T.

Portland—
Hoover, Linn
Rau, Weldon W.
Stewart, Roscoe Emerson

PENNSYLVANIA

Bethlehem—
Willard, Bradford

Bird-in-Hand—
Moss, John Hall

Havertown—
Osmond, John C., Jr.

Philadelphia—
Kammerer, John Craig
Weeks, H. J.

Pittsburgh—
Cox, Ben B.
Fettke, Charles R.
Hedberg, Hollis D.

State College—
Griffiths, J. C.
Krynine, Paul D.
Swartz, Frank M.

RHODE ISLAND

Kingston—
Donohue, John J.
Garrison, Louis Eldred

SOUTH DAKOTA

Rapid City—
Tullis, Edward L.

Vermillion—
Stevenson, Robert Evans

TEXAS

Abilene—
Conselman, Frank B.
Fountain, H. C.
Morrison, Robert E.
Weart, Richard C.
Woodside, Philip R.
Zimmerman, Donald A.
Zinser, Robert W.

Amarillo—
Britt, Harry M., Jr.
Buck, Charles E.
Lohman, Clarence, Jr.

Austin—
Adkins, W. S.
Barnes, Virgil E.
Damon, H. Gordon
Eargle, D. Hoye
Ellison, Samuel P., Jr.
Folk, Robert L.
Gurel, Mehmet
Horton, Claude W.
Krause, Erwin Koerps
Lonsdale, John T.
Lundelius, Ernest L., Jr.
Morey, Philip S.
Stenzel, H. B.
Twining, John T.
Whitney, F. L.

Bellaire—
Holliday, Samuel
Setzer, Francis M.
Beaumont—
Eveland, Harmon E.
College Station—
Gimbrede, Louis de A.
Lynch, Shirley A.
Thompson, Warren C.
Corpus Christi—
Holcomb, Charles W.
Owens, Frith Cravens
Williams, Harry F.
Dallas—
Albritton, Claude C., Jr.
Alexander, C. I.
Billingsley, Harold Ray
Bradfield, Herbert H.
Brooks, James Elwood
Clark, John W.
Cruse, John S., Jr.
DeGolyer, E.
Feray, Dan Edwards
Hamilton, I. B.
MacNaughton, Lewis W.
McNulty, Charles Lee, Jr.
Moreman, Walter L.
Perkins, Bob F.
Sellin, H. A.
Sexton, James V.
Taylor, Jack A.
Thompson, S. A.
Waters, James A.
Yenne, Keith A.
El Paso—
Nelson, Lloyd A.
Prudich, Frank
Fort Worth—
Donoghue, David
Harges, Marvin E.
Hendricks, Leo
Matthews, William H., III
Schweers, Richard Henry
Stewart, Wendell J.
Upson, M. E.
Winton, W. M.
Houston—
Albers, Charles C.
Baker, William A., Jr.
Bannahan, Annabelle Richardson
Barker, R. Wright
Bell, Olin G.
Bradley, John S.
Bright, Anna Lou
Brouwer, Johannes
Bush, James
Campbell, Curran R.
Carstens, Fred D.
Colle, Jack O.
Cotton, Edgar A.
Cram, Ira H.
Crouch, Robert W.
Denham, Richard L.
Deussen, Alexander
Ellis, Albert D., Jr.
Fan, Paul H.
Ferguson, H. C.
Fisk, Harold N.
Garrett, J. B., Jr.
Gilkison, Dwight C.
Goodrich, Paul K.
Greenman, Norman N.
Grubbs, David M.
Halbouty, M. T.
Halsted, Morris E.
Hanna, Marcus A.
Hodges, Clifford H.
Hornberger, Joseph, Jr.
Ikins, William C.
Kirby, Louie C.
Koenig, Karl J.
Levinson, Stuart A.
Ludwick, John C.
Malicoat, Arthur F.
Martyn, Phil F.
McLean, Clarence M., III
Montgomery, J. C.
Moore, Jean M.
Morrison, T. E.
Nelson, Paul Hugh
Overton, Charles K.
Parker, William G.
Petrusek, Benjamin J.
Phillips, Henry H.
Pyeatt, Lloyd M.
Quigley, Claude M., Jr.
Reiter, W. A.
Rolshausen, F. W.
Sawin, Horace J.
Scott, Edward W.
Selig, A. L.
Stephenson, Morton B.
Stevenson, Frank V.
Stubbs, Sidney A.
Stuckey, Charles W., Jr.
Tatum, Emmett P.
Trowbridge, A. C.
Walter, Joe C., Jr.
West, Glen D.
Westmoreland, Frank S.
Whipple, G. Leslie
Wilson, James Lee
Wood, Mary C.
Woods, Raymond D.
La Grange—
Kirsch, M. Ivo, Jr.
Lubbock—
Alexander, W. H., Jr.
Brand, John Paul
Sidwell, Raymond
McAllen—
Means, John A.
Midland—
Adams, John Emery
Adent, William A.
Arick, Millard B.
Baker, Maylon S., Jr.
Baldwin, Don C.
Frenzel, Hugh N.
Hollingsworth, R. V.
Mills, Lloyd C.
Montgomery, James Harvey
Rothrock, Howard E.
Scobey, Ellis H.
Spencer, Maria
Stead, Frederick L.
Sutherland, Patrick K.
Williams, Harold L
Wimbish, Forrest Edwin
Mineral Wells—
Chatham, E. Walter, Jr.
San Angelo—
Roper, Frank C.
San Antonio—
Grasso, Volker C.
Owen, Edgar W.
Petty, Dabney E.
Ritts, L. Chase, Jr.
Rogers, James K.
Sandidge, John R.
Scrafford, J. Bruce
Siemer, William J.
Still, J. T.
Tartamella, Natale John
Seguin—
Kniker, Hedwig T.
Seymour—
Kemp, Augusta Hasslock
Tyler—
Avant, Joseph B.
Bunch, Rosella L.
Gayer, Siegmund T.
Humble, Emmett A.
Hurlbut, Elvin M., Jr.
Magaw, Mary Catherine
Wichita Falls—
Drake, Robert T.
Gibson, William C.
Richards, David T.
Wright, Wayne P.

UTAH

Salt Lake City—
Brown, Alfred L.
Elias, Gregory K.
Jones, Daniel J.

VIRGINIA

Alexandria—
Goldman, Marcus I.
McLean, James D., Jr.
Falls Church—
Palmer, Allison Ralph
Lexington—
Stow, Marcellus H.
New Market—
Herbert, Paul, Jr.

WASHINGTON

Pullman—
Scott, W. Frank
Seattle—
Ball, John Rice
Biesiot, Peter
Coombs, Howard A.
Mallory, V. Standish
Pfeiffer, David H.
Wheeler, Harry E.
Spokane—
Freeman, Val LeRoy

WEST VIRGINIA

Clarksburg—
Bayles, Robert E.
Morgantown—
Heald, Milton T.

WISCONSIN

Beloit—
Croneis, Carey
Madison—
Bostwick, David A.
King, William Edward
Moore, Walter L.
Sanderson, George A., Jr.
Thompson, M. L.
Tyler, Stanley A.
Zeller, Edward J.
Platteville—
Agnew, Allen F.

WYOMING

Basin—
Lease, Leslie W.
Casper—
Barkell, Clifford A.
Dresser, Hugh
Peterson, James A.
Reinhart, Philip W.
Swirczynski, Richard Paul
Worland—
Hanson, Alvin M.

OUTSIDE THE UNITED STATES

ALBERTA

Calgary—
Atkinson, Eric
Burgers, Willem
Chilton, Mertie Ann
Crombie, Gordon Peers
Erickson, Robert H.
Fong, George
Goodman, A. J.
Hilgers, C. L. L.
Moore, Peter Fitzgerald
Renaud, Jacques E.
Sproule, J. C.
Wegmuller, Walter
Wickenden, Robert T. D.
Williams, Edwin Philp
Wonfor, John S.
Workman, Lewis E.
Edmonton—
Bruseker, T. J. M.
MacKay, Ian H.
Nielsen, Arne R.
Rimbey—
Rands, Claud N.

ALGERIA

Alger—
Dunand, Georgette
Magne, Jean
Termier, Henri

AUSTRALIA

Adelaide—
Glaessner, Martin Fritz
Boronia—
Nadeau, Betty Kellett
Canberra—
Crespin, Irene
Sydney—
Browne, Ida A.

AUSTRIA

Vienna—
Schors, W. W. L.

BARBADOS

Bridgetown—
Ronai, Peter H.

BELGIAN CONGO

Leopoldville—
Zimmermann, Fritz R.

BELGIUM

Brussels—
Brognon, Georges P. G.
Lombard, Augustin E.
Gand—
Tavernier, R.
Liege—
Calembert, Leon M. C.
Ubaghs, Georges J. C.
Louvain—
Gullentops, Frank B.

BRAZIL

Bahia—
Brantly, John E., Jr.
Santa Catarina—
Putzer, Hannfrit

BRITISH COLUMBIA

Vancouver—
Hughes, Richard David

COLOMBIA

Bogota—
Maurenbrecher, A. L. F. J.
Nelson, Hans W.
Petters, Viktor
Schoonover, Jack Gardner

CUBA

Havana—
Acosta-Gimenez, Jose T.
Fernandez, Ramona
Truitt, Paul B.

DENMARK

Charlottenlund—
Gray, Jane
Copenhagen—
Pyre, Augustin

EGYPT

Alexandria—
Higazy, Riad A.
Nakkady, S. E.
Cairo—
Arni, Paul
Said, Rushdy
Samaan, Sobhi Mikhail
Shukri, N. M.
Souaya, Fernand J.

ENGLAND

Bexhill-on-Sea—
Andrews, B. G.
Bristol—
Loupekine, I. S.
Cambridge—
Allen, Percival
Durham—
Rhodes, Frank H. T.
Liverpool—
Bathurst, Robin G. C.
Manchester—
Eagar, Richard M. C.
Tenterden—
MacFadyen, W. A.

FRANCE

Bourg-la-Reine—
Riviere, A.
Dijon (Cote d'Or)—
Ciry, Raymond Maurice
Nancy—
Avias, Jacques
Paris—
Bourcart, J. J.
Cuvillier, Jean
De Cizancourt, Maria
Vatan, A.
Pau Bss. Pyr—
Sacal, Vincent

GERMANY

Celle—
Fuchtbauer, Hans
Wick, Werner
Eutin—
Wetzel, Otto
Gottingen—
Correns, Carl W.
Hamburg—
Illies, Jurgen H.
Pratje, Otto
Hannover—
Bentz, Alfred
Bettenstaedt, Franz
Munich—
Hagn, Herbert

INDIA

Calcutta—
Jacob, Kurien

Digboi—
Baxter, George W.
Madras—
Kasthuri, A. K.

IRAN

Teheran—
Furrer, Max Adolph

IRAQ

Kirkuk—
Dunnington, Harold V.
Van Bellen, Robert Carel

IRELAND

Belfast—
Schwarzacher, Walther

ITALY

Cagliari—
Caria, Ida Comaschi
Ferrara—
Leonardi, Piero
Florence—
Marchetti, Marco Piero
Merla, Giovanni
Migliorini, Carlo I.
Milano—
Alliata, Enrico di N.
Modena—
Gallitelli, E. Montanaro
Naples—
Mirigliano, Giuseppe
Palermo—
Cipolla, Francesco
De Stefani, Teodosio
Pisa—
Trevisan, Livio
Rome—
Fabiani, Ramiro
Sicily—
Flores, Giovanni

JAPAN

Fukuoka—
Toriyama, Ryuzo
Kyoto—
Chiji, Manzo
Makiyama, Jiro
Sendai—
Hanzawa, Shoshiro
Hatai, Kotora
Tokyo—
Fujimoto, Haruyoshi
Kanehara, Kinji
Oinomikado, Tsuneteru
Sakakura, Katsuhiko
Stach, Leo W.
Sudo, Toshio

MEXICO

Mexico City—
Alvarez, Javier
Alvarez, Manuel, Jr.
Arellano, A. R. V.
Folk, Stewart H.
Guzman, Eduardo Jose
Mullerried, F. K. G.
Robeck, Raymond C.

MOROCCO

Rabat—
Schoeffler, Jacques

MOZAMBIQUE

Lourenco Marques—
Rabanit, Paul

NETHERLANDS

Amsterdam—
Van Andel, Tjeerd Hendrik
Van Baren, F. A.
Doorn—
Weynschenk, R.
Groningen—
Kuenen, Ph. H.
Van Straaten, L. M. J. U.
Heerlen—
Dijkstra, Sybren Jan
Leiden—
Tromp, S. W.
Wissema, G. G.
Oegstgeest—
Niggli, Ernst Heinrich
The Hague—
Emeis, J. D.
Hofker, Jan
Van Weelden, Arie
Tiel—
Bannink, Dirk D.
Wageningen—
Doeglas, Dirk Jacobus
Zeist—
Drooger, Cornelis Willem

NETHERLANDS GUIANA

Paramaribo—
Schols, Hendrik

NIGERIA

Owerri—
Baggelaar, Hermanus
Schweighauser, Jacob

PAKISTAN

Quetta—
Khan, M. H.

PERU

La Oroya—
Iten, Ken W. B.
Negritos—
Stainforth, Robert M.
Talara—
Fischer, Alfred G.
Youngquist, Walter L.

PHILIPPINE ISLANDS

Lucena—
Daleon, Benjamin A.

PORTUGAL

Coimbra—
De Carvalho, G. Soares

SASKATCHEWAN

Regina—
Chakravorty, Sailendra K.
Grant, Drane Fones
Munyan, Arthur C.

SAUDI ARABIA

Dhahran—
Furnish, William M.
Redmond, Charles D.
Seager, O. A.
Wacker, Robert Wm.

SCOTLAND

Edinburgh—
Wright, James

SOUTHERN RHODESIA

Bulawayo—
Bond, Geoffrey

SPAIN

Madrid—
Melendez, Bermudo
Soller (Balearic Islands)—
Colom, Guillermo

SUMATRA

Palembang—
Stone, Benton

SWEDEN

Boliden—
Grip, Erland
Bromma—
Erdtman, Gunnar
Stockholm—
Mellis, Otto

SWITZERLAND

Basle—
Beckmann, Jean-Pierre
Tschopp, H. I.
Vonderschmitt, Louis
Berne—
Rutsch, R. F.
Fribourg—
Tercier, Jean
Lausanne—
Bersier, Arnold
Neuchatel—
Wegmann, Eugene
Wabern-Bern—
Hugi, Theodor

TRINIDAD

Palo Seco—
Wirz, A. E.
Pointe-a-Pierre—
Kugler, H. G.

TUNISIA

Sfax—
Burollet, Pierre F.

TURKEY

Ankara—
Erk, Ahmet Suat
Tasman, Mehlika

VENEZUELA

Caracas—
Banks, Luis Maria
Bermudez, Pedro J.
Bursch, Jacobus George
Dusenbury, A. N., Jr.
Gomez, Jose Royo y
Hadley, Wade H., Jr.,
Johnson, Robert M.
Jones, Verner
Keyzer, Franz Gaspard
Mandra, Alba
Marks, Jay Glenn
Maync, Wolf
Renz, Hans Hermann
Rod, Emile
Szenk, Bogustaw J.
Winkler, Virgil D.
Young, Gordon A.
Caripito—
Becker, Leroy E.
Jusepin—
Sowers, Gordon M.
Lagunillas—
Howard, Jesse James
Maracaibo—
Anisgard, Harry W.
Kuyl, Otto Samuel
Patman, William E.
Sanders, John Warren
Van Raadshooven, Bertram
Walker, Bruce H.
Quiriquire—
Daetwyler, Calvin C.